

Fig. 1a

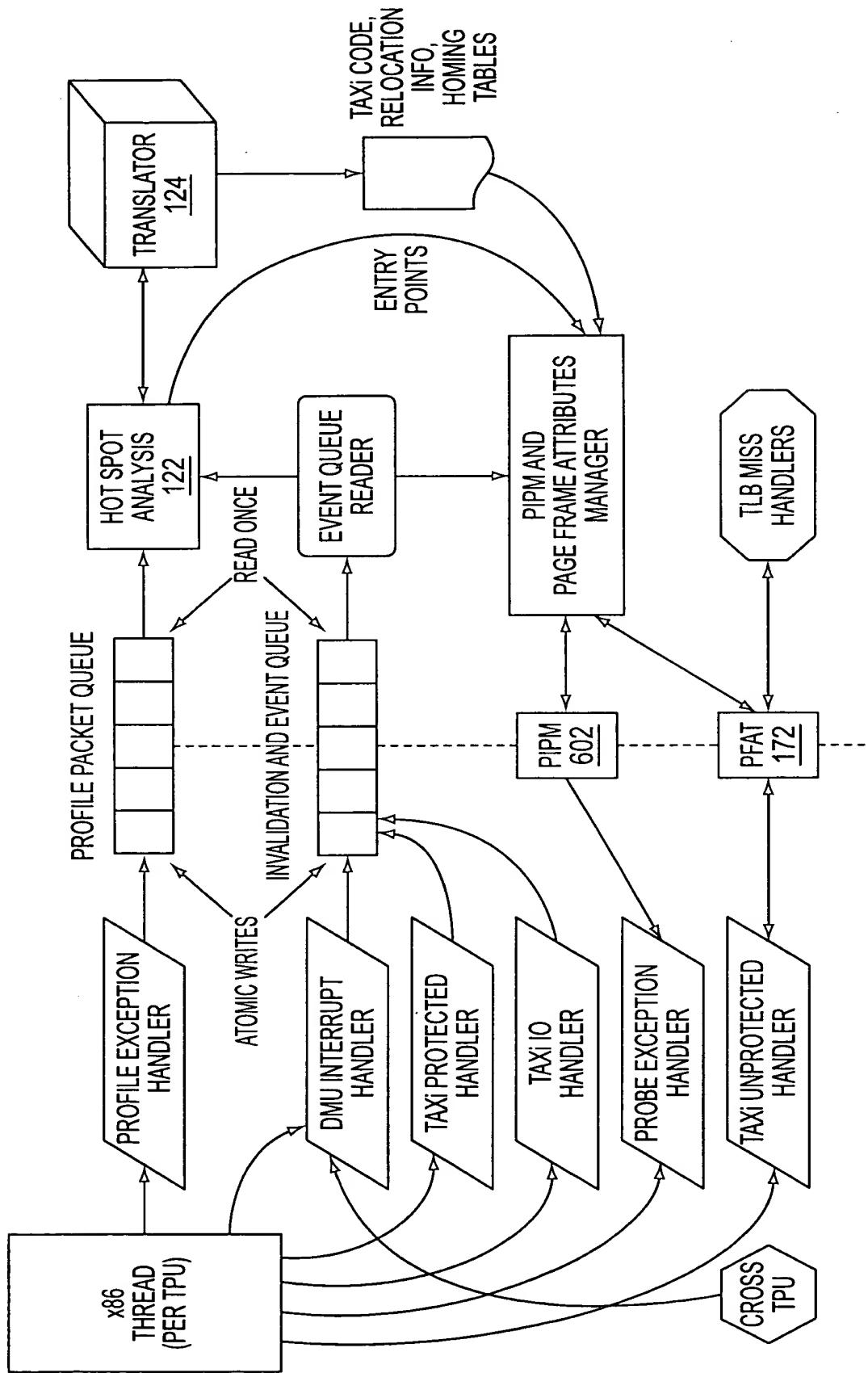
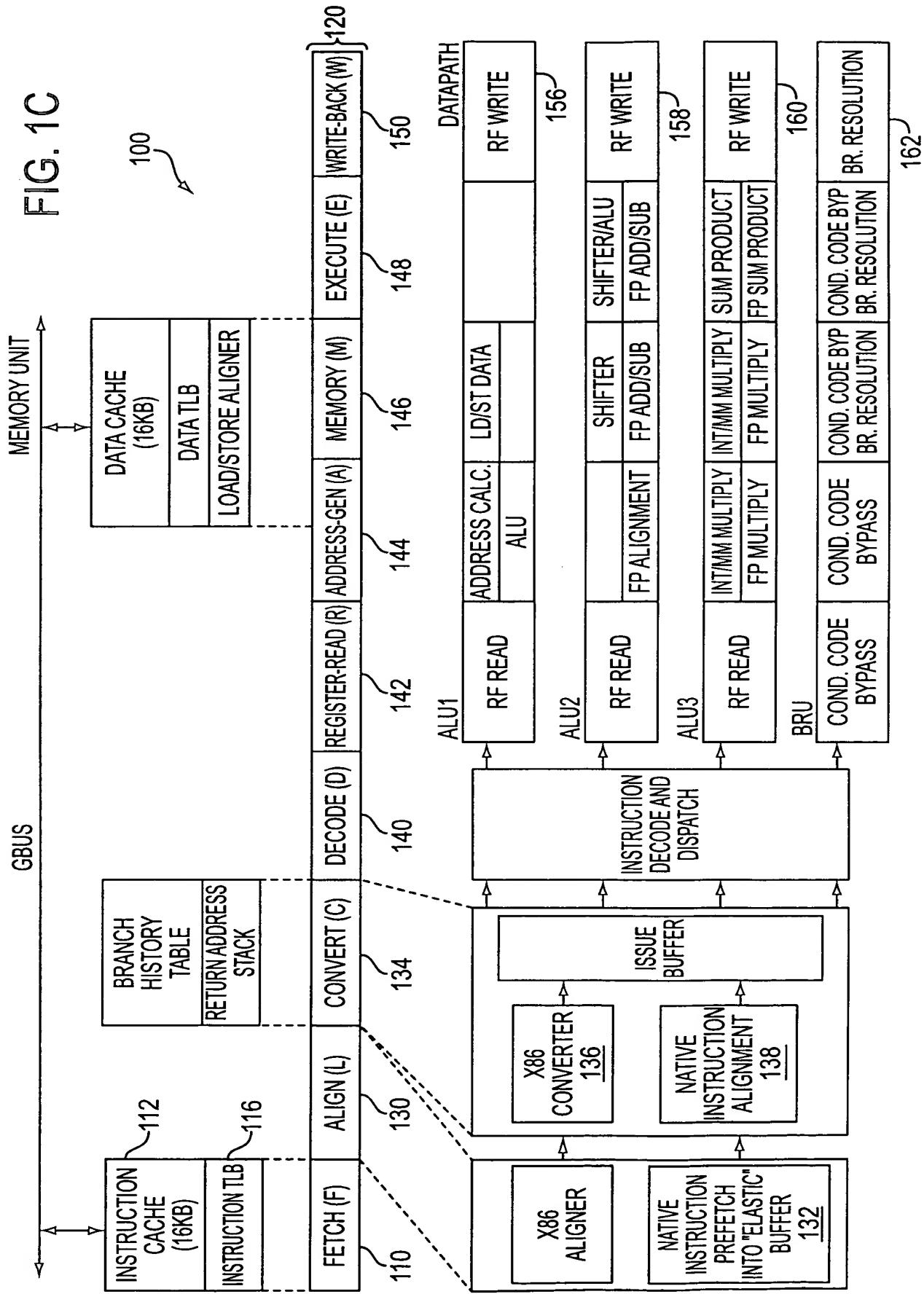


FIG. 1B

FIG. 1C



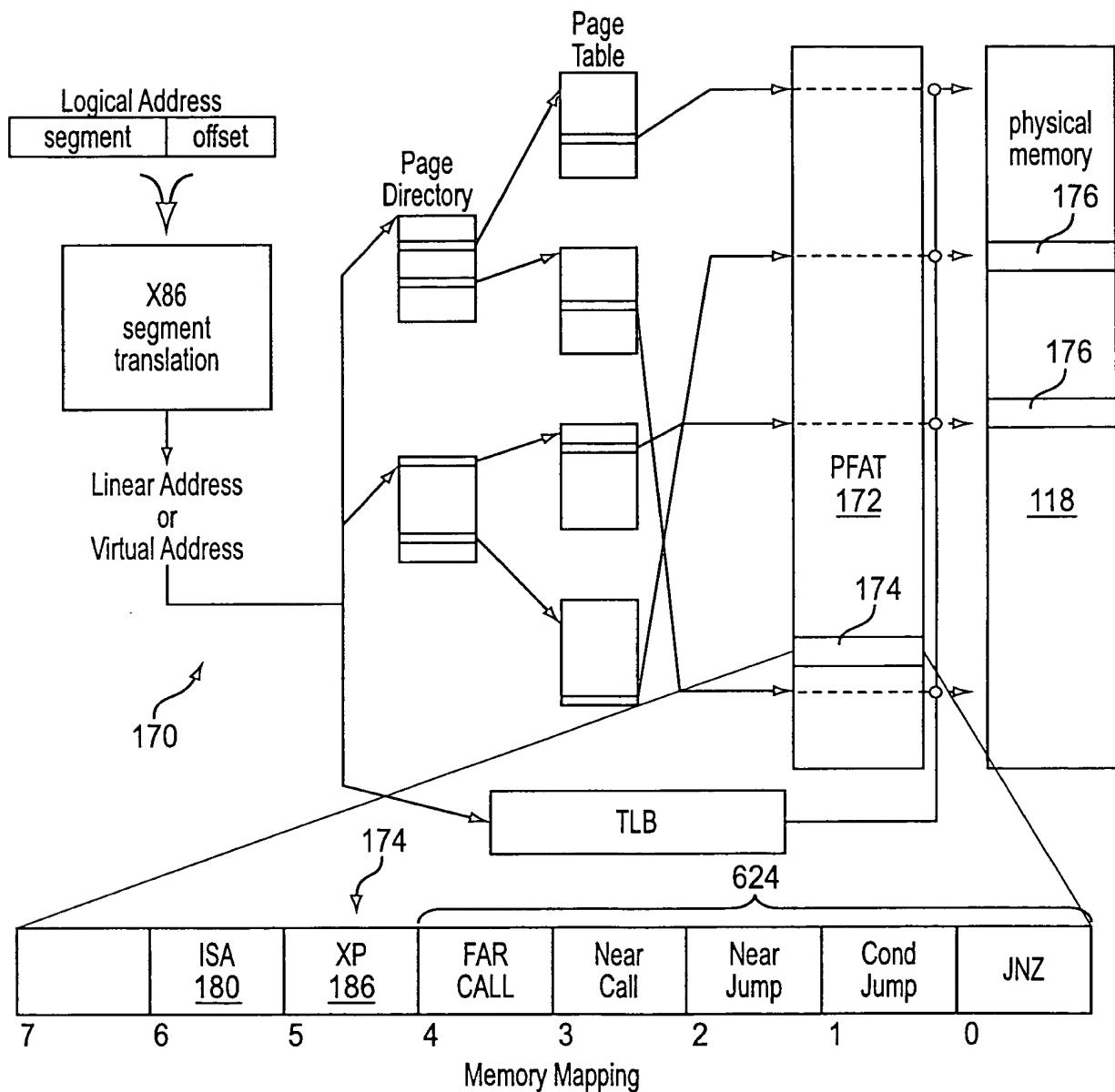


FIG. 1D

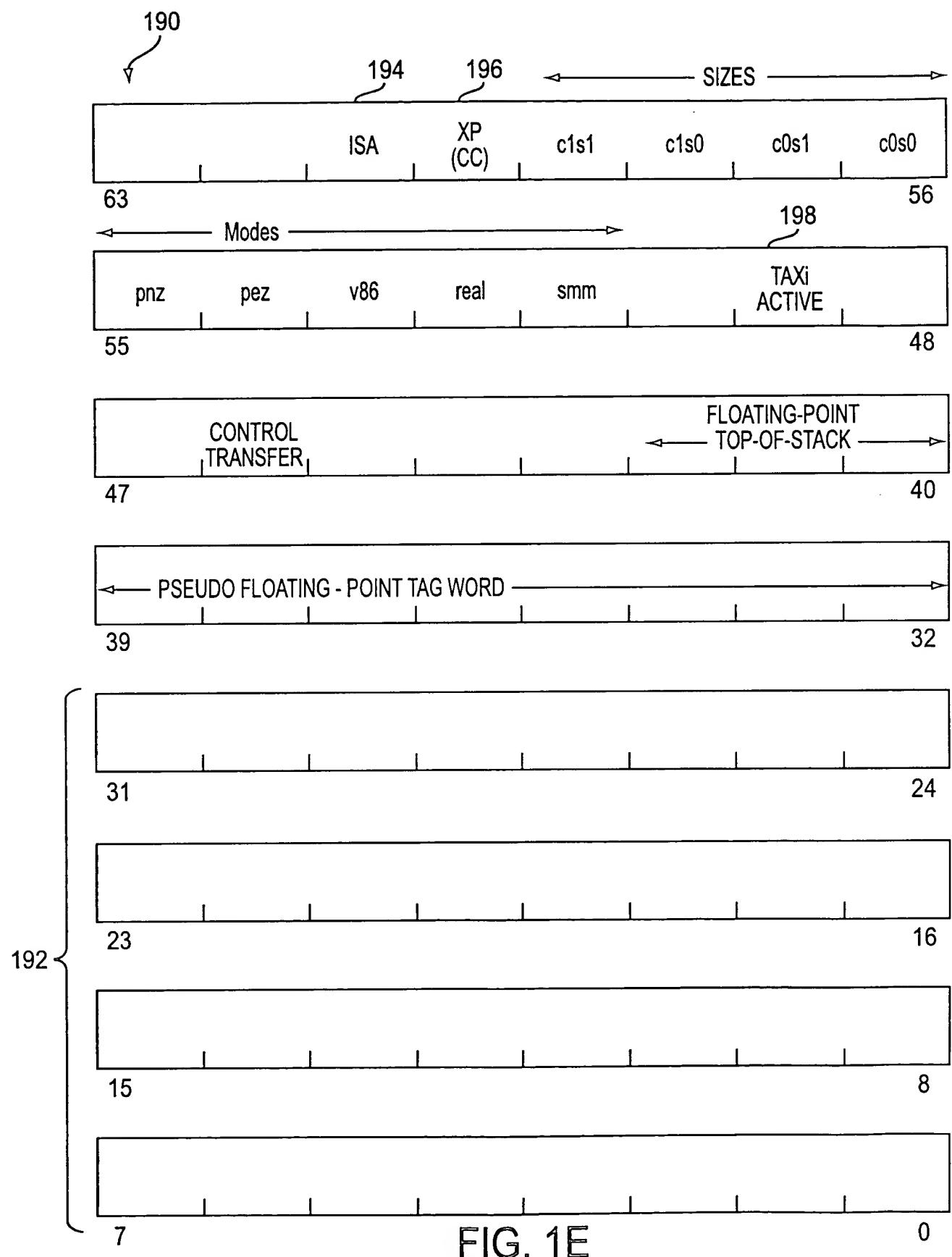


FIG. 1E

I-TLB PROPERTY BITS	DECODED PROPERTY VALUES			PROTECTED INTERPRETATION	INSTRUCTIONS SENT TO:	COLLECT PROFILE TRACE- PACKETS?	PROBE FOR TRANSLATED CODE	I/O MEMORY REFERENCE EXCEPTIONS
	ISA 194	CC 200						
00	TAP	TAP	NO	NATIVE CODE OBSERVING NATIVE RISCY CALLING CONVENTIONS	NATIVE DECODER	NO	NO	FAULT IF SEG.tio
01	TAP	x86	NO	NATIVE CODE OBSERVING x86 CALLING CONVENTIONS	NATIVE DECODER	NO	NO	FAULT IF SEG.tio
10	x86	x86	NO	x86 CODE, UNPROTECTED - TAXI PROFILE COLLECTION ONLY	x86 HW CONVERTER	IF ENABLED	NO	TRAP IF PROFILING
11	x86	x86	YES	x86 CODE, PROTECTED - TAXI CODE MAY BE AVAILABLE	x86 HW CONVERTER	IF ENABLED	BASED ON I-TLB PROBE ATTRIBUTES	TRAP IF PROFILING

180,182, 184,186
184,186

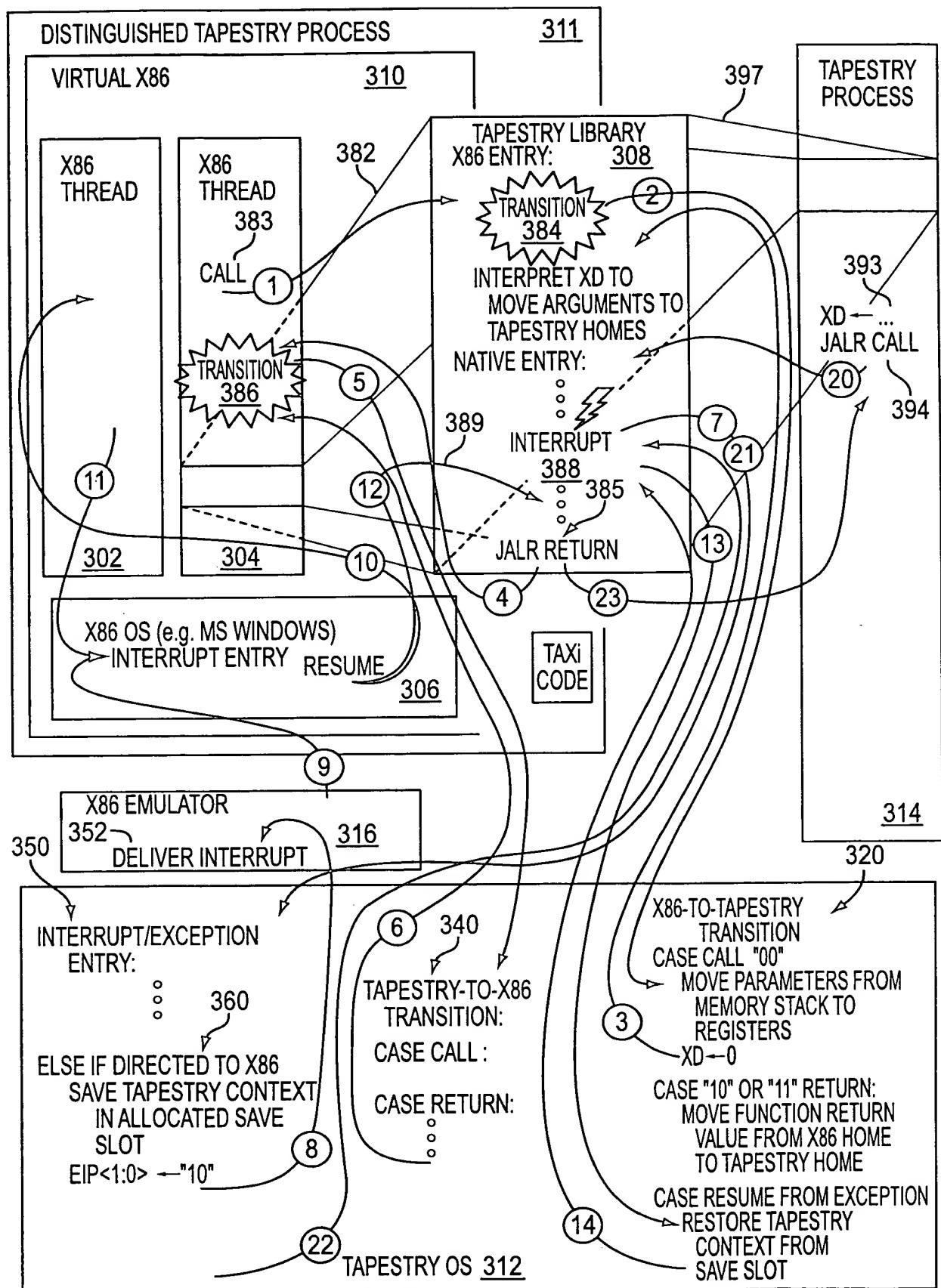
FIG. 2A

204	TRANSITION (SOURCE => DEST) ISA & CC PROPERTY VALUES	HANDLER ACTION
212	00 => 00	NO TRANSITION EXCEPTION
214	00 => 01	VECT_xxx_X86_CC EXCEPTION - HANDLER CONVERTS FROM NATIVE TO x86 CONVENTIONS
216	00 => 1x	VECT_xxx_X86_CC EXCEPTION - HANDLER CONVERTS FROM NATIVE x86 CONVENTIONS, SETS UP EXPECTED EMULATOR AND PROFILING STATE
218	01 => 00	VECT_xxx_TAP_CC EXCEPTION - HANDLER CONVERTS FROM x86 TO NATIVE CONVENTIONS
220	01 => 01	NO TRANSITION EXCEPTION
222	01 => 1x	VECT_X86_ISA EXCEPTION [CONDITIONAL BASED ON PCW.X86_ISA_ENABLE FLAG] - SETS UP EXPECTED EMULATOR AND PROFILING STATE
224	1x => 00	VECT_xxx_TAP_CC EXCEPTION - HANDLER CONVERTS FROM x86 TO NATIVE CONVENTIONS
226	1x => 01	VECT_TAP_ISA EXCEPTION [CONDITIONAL BASED PCW.TAP_ISA_ENABLE FLAG] - NO CONVENTION CONVERSION NECESSARY
228	1x => 10	NO TRANSITION EXCEPTION - [PROFILE COMPLETE POSSIBLE, PROBE POSSIBLE]
230	1x => 11	NO TRANSITION EXCEPTION - [PROFILE COMPLETE POSSIBLE, PROBE NOT POSSIBLE]

FIG. 2B

242	NAME	DESCRIPTION	TYPE
244	VECT_call_X86_CC	PUSH ARGS, RETURN ADDRESS, SET UP x86 STATE	FAULT ON TARGET INSTRUCTION
246	VECT_jump_X86_CC	SET UP x86 STATE	FAULT ON TARGET INSTRUCTION
248	VECT_ret_no_fp_X86_CC	RETURN VALUE TO EAX:EDX, SET UP x86 STATE	FAULT ON TARGET INSTRUCTION
250	VECT_ret_fp_X86_CC	RETURN VALUE TO x86 FP STACK, SET UP x86 STATE	FAULT ON TARGET INSTRUCTION
252	VECT_call_TAP_CC	x86 STACK ARGS, RETURN ADDRESS TO REGISTERS	FAULT ON TARGET INSTRUCTION
254	VECT_jump_TAP_CC	x86 STACK ARGS TO REGISTERS	FAULT ON TARGET INSTRUCTION
256	VECT_ret_no_fp_TAP_CC	RETURN VALUE TO RV0	FAULT ON TARGET INSTRUCTION
	VECT_ret_any_TAP_CC	RETURN TYPE UNKNOWN, SETUP RV0 AND RVDP	FAULT ON TARGET INSTRUCTION

FIG. 2C



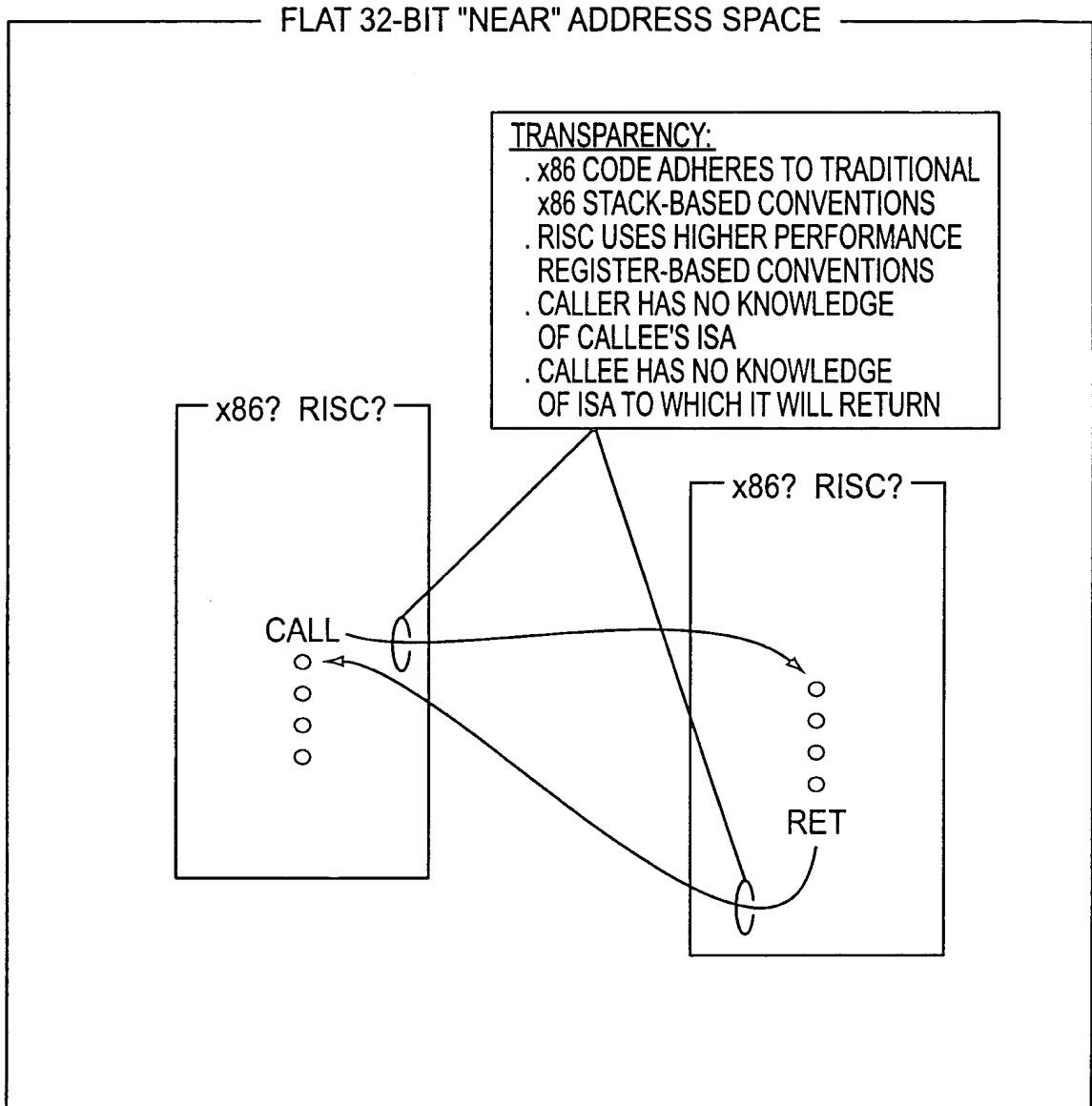
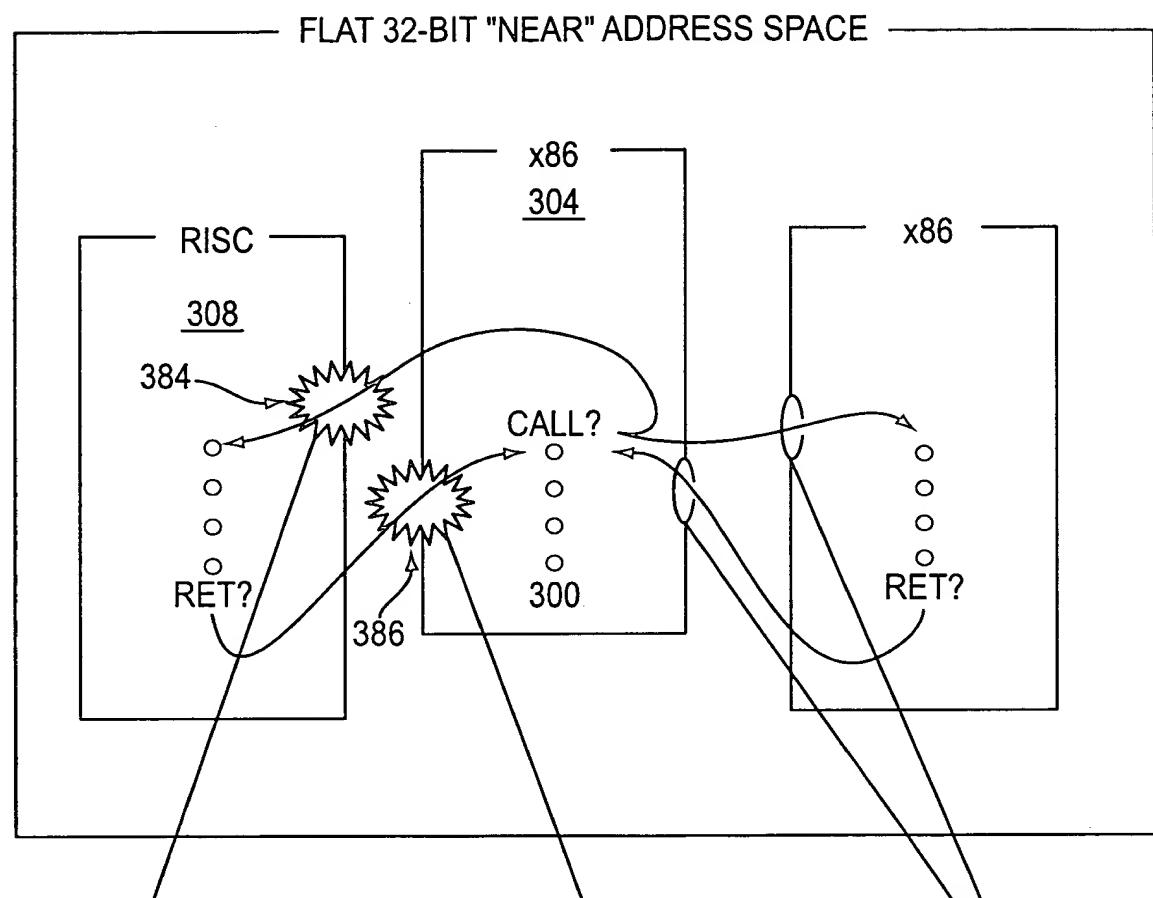


FIG. 3B



x86 → RISC TRANSITION:
MAP x86 CALL TO RISC
322 (FIG. 3H)

RISC → x86 TRANSITION:
MAP x86 RETURN TO RISC
342 (FIG. 3I)

NO ISA TRANSITION:
NO MAPPING REQUIRED

FIG. 3C

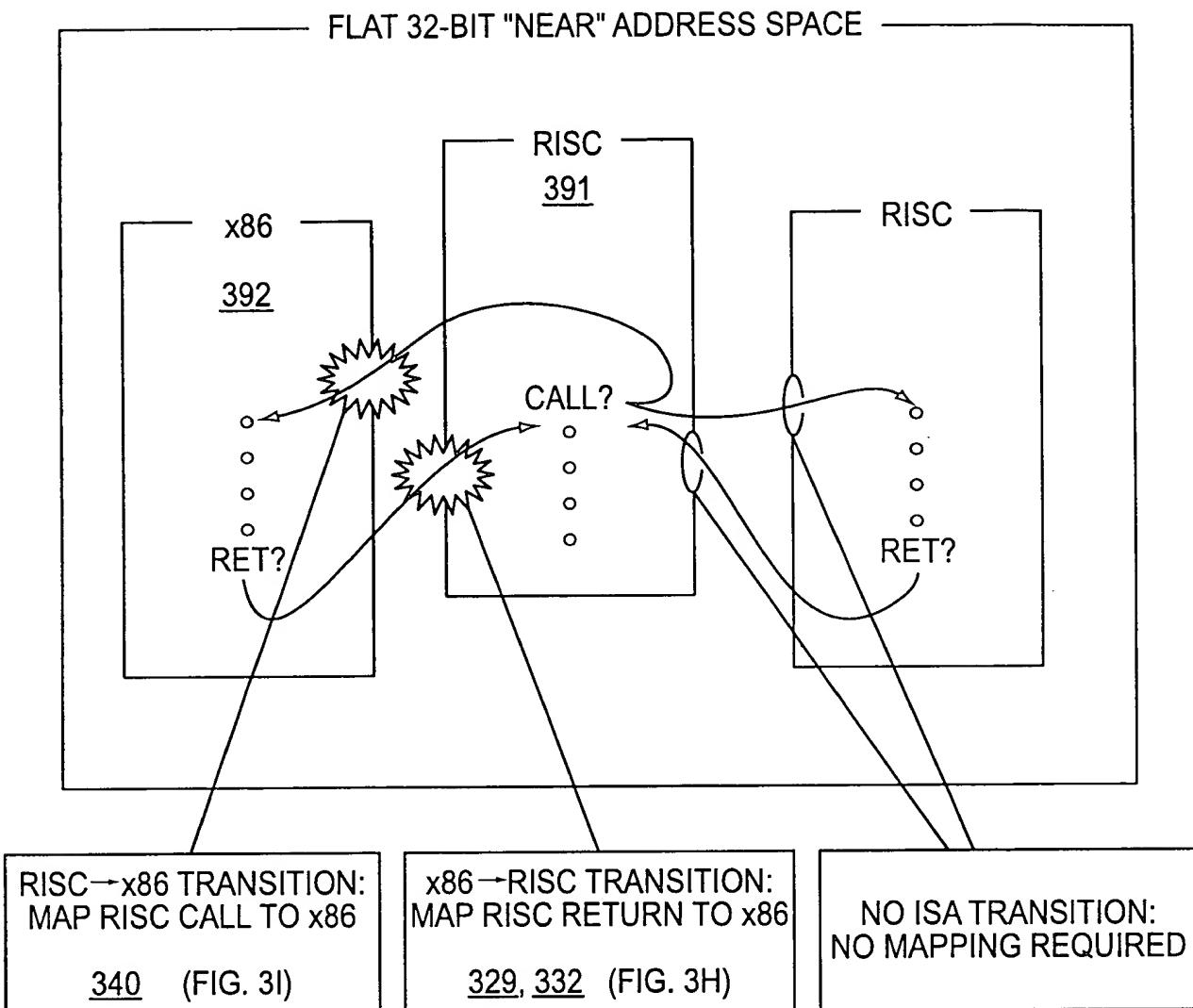
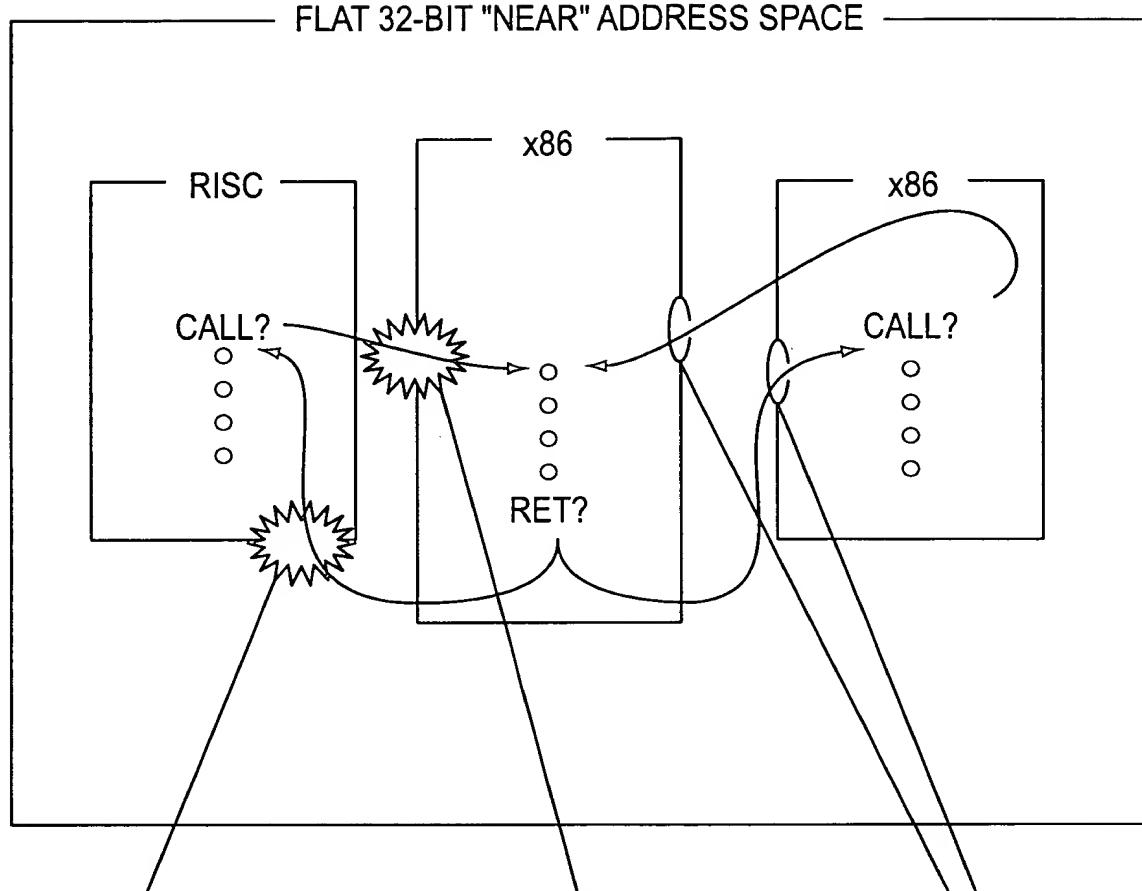


FIG. 3D

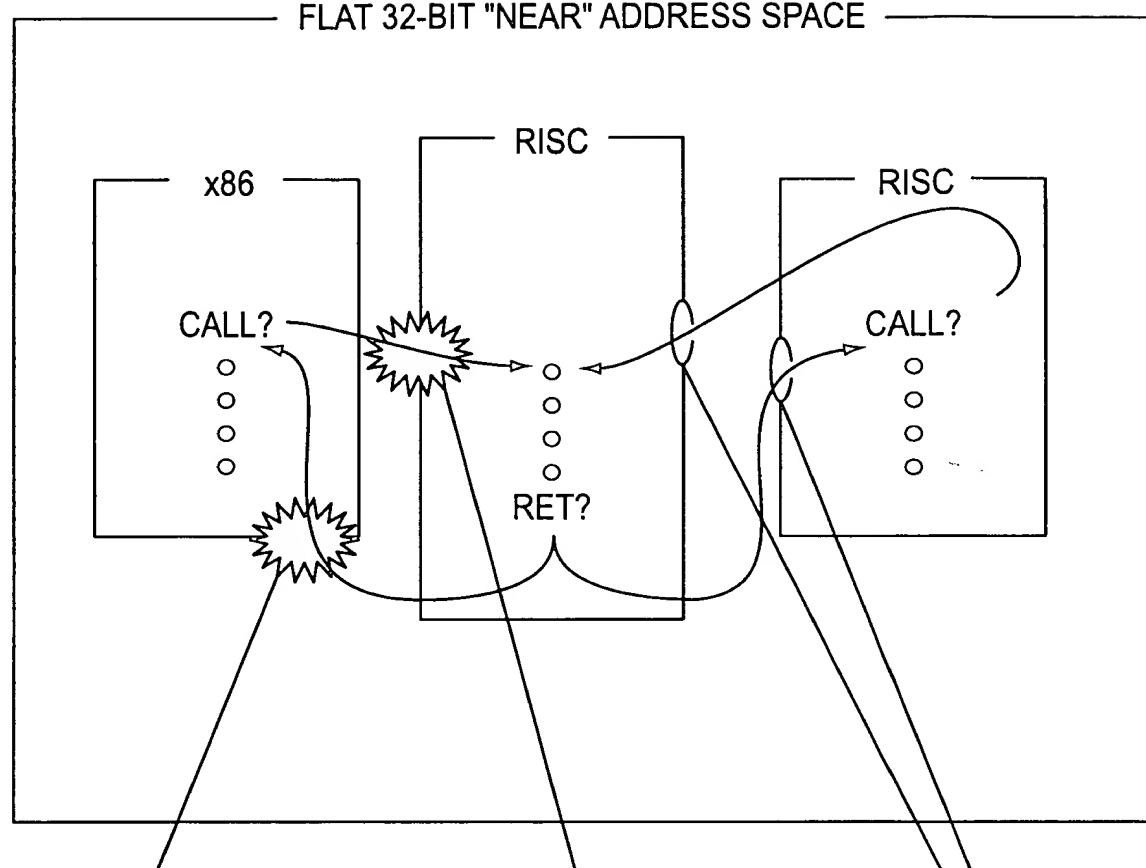


x86 → RISC TRANSITION:
MAP RISC RETURN TO x86
329, 332 (FIG. 3H)

RISC → x86 TRANSITION:
MAP RISC CALL TO x86
343-348 (FIG. 3I)

NO ISA TRANSITION:
NO MAPPING REQUIRED

FIG. 3E



RISC → x86 TRANSITION:
MAP x86 RETURN TO RISC

342 (FIG. 3I)

x86 → RISC TRANSITION:
MAP x86 CALL TO RISC

322 (FIG. 3H)

NO ISA TRANSITION:
NO MAPPING REQUIRED

FIG. 3F

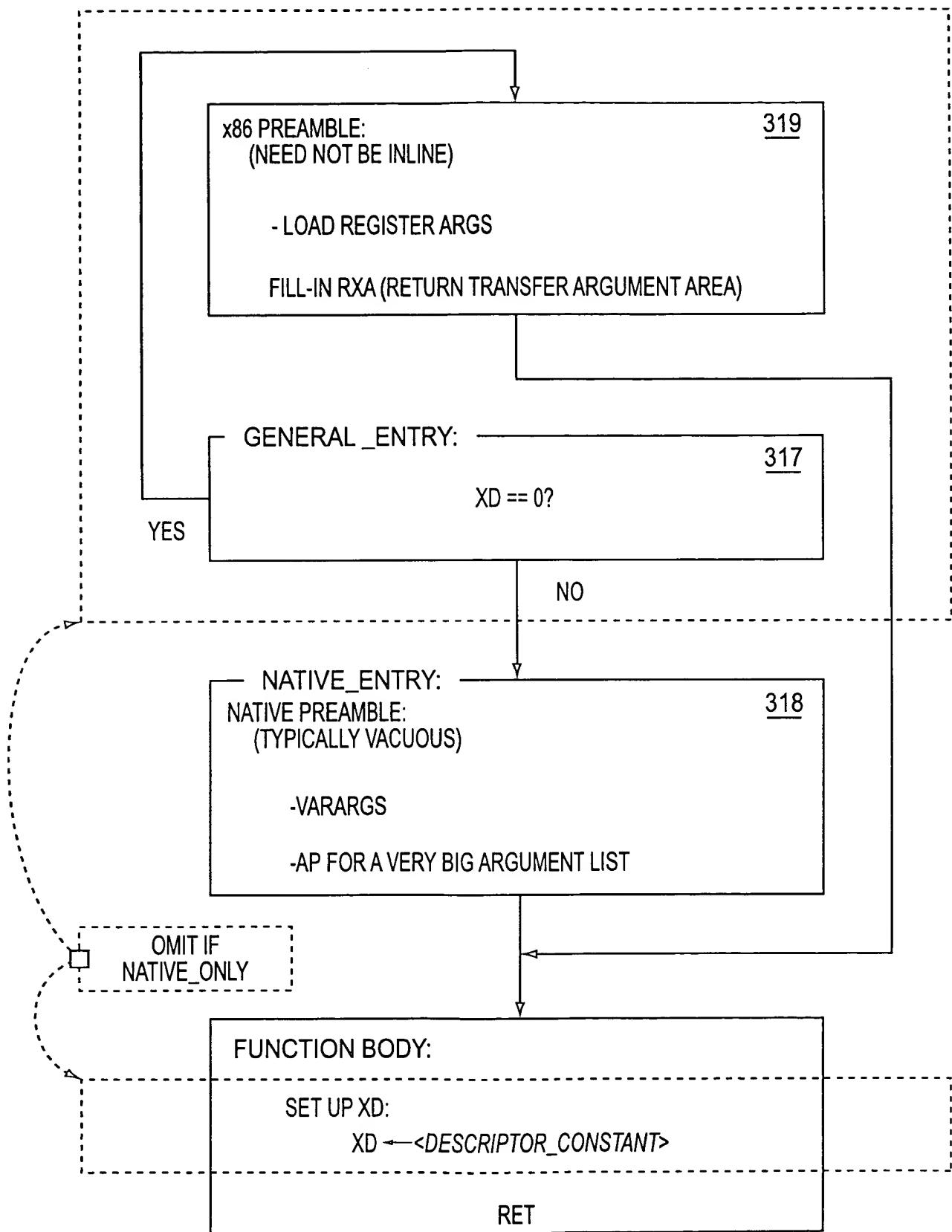


FIG. 3G

X86-to Tapestry transition exception handler

// This handler is entered under the following conditions:
 // 1. An x86 caller invokes a native function
 // 2. An x86 function returns to a native caller
 // 3. x86 software returns to or resumes an interrupted native function following
 // an external asynchronous interrupt, a processor exception, or a context switch

321
 dispatch on the two least-significant bits of the destination address {
 case "00" // calling a native subprogram
 // copy linkage and stack frame information and call parameters from the memory
 // stack to the analogous Tapestry registers
 LR ← [SP++] // set up linkage register 323
 AP ← SP // address of first argument 324
 SP ← SP - 8 // allocate return transfer argument area 326
 SP ← SP & (-32) // round the stack pointer down to a 0 mod 32 boundary 327
 XD ← 0 // inform callee that caller uses X86 calling conventions 328

case "01" // resuming an X86 thread suspended during execution of a native routine
 if the redundant copies of the save slot number in EAX and EDX do not match or if
 the redundant copies of the timestamp in EBX:ECX and ESI:EDI do not match { } 371
 // some form of bug or thread corruption has been detected
 goto TAPESTRY_CRASH_SYSTEM(thread-corruption-error-code) 372

} 373
 save the EBX:ECX timestamp in a 64-bit exception handler temporary register
 (this will not be overwritten during restoration of the full native context) 373

use save slot number in EAX to locate actual save slot storage 374
 restore full entire native context (includes new values for all x86 registers) 375
 if save slot's timestamp does not match the saved timestamp { 376

// save slot has been reallocated; save slot exhaustion has been detected
 goto TAPESTRY_CRASH_SYSTEM(save-slot-overwritten-error-code) 377

} 378
 free the save slot

case "10" // returning from X86 callee to native caller, result already in registers
 RV0<63:32> ← edx<31:0> // in case result is 64 bits 333
 convert the FP top-of-stack value from 80 bit X86 form to 64-bit form in RVDP 334

SP ← ESI // restore SP from time of call 337

case "11" // returning from X86 callee to native caller, load large result from memory
 RV0..RV3 ← load 32 bytes from [ESI-32] // (guaranteed naturally aligned) 330

SP ← ESI // restore SP from time of call 337

} 338
 EPC ← EPC & -4 // reset the two low-order bits to zero 336
 RFE 338

320
 ↗

322

371

370

332

329

337

FIG. 3H

Tapestry-to-X86 transition exception handler

// This handler is entered under the following conditions:
 // 1. a native caller invokes an x86 function
 // 2. a native function returns to an x86 caller

switch on XD<3:0> { ~341

XD_RET_FP: // result type is floating point
 FO/FI ← FINFLATE.de(RVDP) // X86 FP results are 80 bits
 SP ← from RXA save // discard RXA, pad, args
 FPCW ← image after FINIT & push // FP stack has 1 entry
 goto EXIT

XD_RET_WRITEBACK: // store result to @RVA, leave RVA in eax
 RVA ← from RXA save // address of result area
 copy decode(XD<8:4>) bytes from RV0..RV3 to [RVA]
 eax ← RVA // X86 expects RVA in eax
 SP ← from RXA save // discard RXA, pad, args
 FPCW ← image after FINIT // FP stack is empty
 goto EXIT

XD_RET_SCALAR: // result in eax:eda
 edx<31:00> ← eax<63:32> // in case result is 64 bits
 SP ← from RXA save // discard RXA, pad, args
 FPCW ← image after FINIT // FP stack is empty
 goto EXIT

XD_CALL_HIDDEN_TEMP: // allocate 32 byte aligned hidden temp ~343
 esi ← SP // stack cut back on return
 SP ← SP - 32 // allocate max size temp } 344
 RVA ← SP // RVA consumed later by RR
 LR<1:0> ← "11" // flag address for return & reload ~345
 goto CALL_COMMON

default: // remaining XD_CALL_xxx encodings
 esi ← SP // stack cut back on return
 LR<1:0> ← "10" // flag address for return ~343

CALL_COMMON: // interpret XD to push and/or reposition args ~347
 [-SP] ← LR // push LR as return address } 346

EXIT: // setup emulator context and profiling ring buffer pointer } 348

}

RFE ~349 // to original target

FIG. 31

350

interrupt/exception handler of Tapestry operating system:

```

// Control vectors here when a synchronous exception or asynchronous interrupt is to be
// exported to / manifested in an x86 machine.

// The interrupt is directed to something within the virtual X86, and thus there is a possibility
// that the X86 operating system will context switch. So we need to distinguish two cases:
// either the running process has only X86 state that is relevant to save, or
// there is extended state that must be saved and associated with the current machine context
// (e.g., extended state in a Tapestry library call in behalf of a process managed by X86 OS)
if execution was interrupted in the converter – EPC.ISA == X86 {
    // no dependence on extended/native state possible, hence no need to save any } 351
    goto EM86_Deliver_Interrupt( interrupt-byte )
} else if EPC.Taxi_Active {
    // A Taxi translated version of some X86 code was running. Taxi will rollback to an
    // x86 instruction boundary. Then, if the rollback was induced by an asynchronous external
    // interrupt, Taxi will deliver the appropriate x86 interrupt. Else, the rollback was induced
    // by a synchronous event so Taxi will resume execution in the converter, retriggering the
    // exception but this time with EPC.ISA == X86
    goto TAXi_Rollback( asynchronous-flag, interrupt-byte ) } 353
} else if EPC.EM86 {
    // The emulator has been interrupted. The emulator is coded to allow for such
    // conditions and permits re-entry during long running routines (e.g. far call through a gate)
    // to deliver external interrupts
    goto EM86_Deliver_Interrupt( interrupt-byte ) } 354
} else {
    // This is the most difficult case - the machine was executing native Tapestry code on
    // behalf of an X86 thread. The X86 operating system may context switch. We must save
    // all native state and be able to locate it again when the x86 thread is resumed.
    361
    allocate a free save slot; if unavailable free the save slot with oldest timestamp and try again
    save the entire native state (both the X86 and the extended state) } 362
    save the X86 EIP in the save slot } 363
    overwrite the two low-order bits of EPC with "01" (will become X86 interrupt EIP)
    store the 64-bit timestamp in the save slot, in the X86 EBX:ECX register pair (and,
        for further security, store a redundant copy in the X86 ESI:EDI register pair) } 364
    store the a number of the allocated save slot in the X86 EAX register (and, again for
        further security, store a redundant copy in the X86 EDX register) } 365
    goto EM86_Deliver_Interrupt( interrupt-byte ) } 369
}

```

FIG. 3J

```

typedef struct {
    save_slot_t *    newer,           // pointer to next-most-recently-allocated save slot } 379c
    save_slot_t *    older;          // pointer to next-older save slot
    unsigned int64   epc;            // saved exception PC/IP
    unsigned int64   pcw;            // saved exception PCW (program control word)
    unsigned int64   registers[63];  // save the 63 writeable general registers } 356 } 355
    ...
    timestamp_t     timestamp;      // timestamp to detect buffer overrun
    int             save_slot_ID;   // ID number of the save slot ~ 358
    boolean          save_slot_is_full; // full / empty flag ~ 357
} save_slot_t;                                ~ 359

save_slot_t *    save_slot_head;    // pointer to the head of the queue ~ 379a
save_slot_t *    save_slot_tail;   // pointer to the tail of the queue ~ 379b

```

system initialization
 reserve several pages of unpaged memory for save slots

FIG. 3K

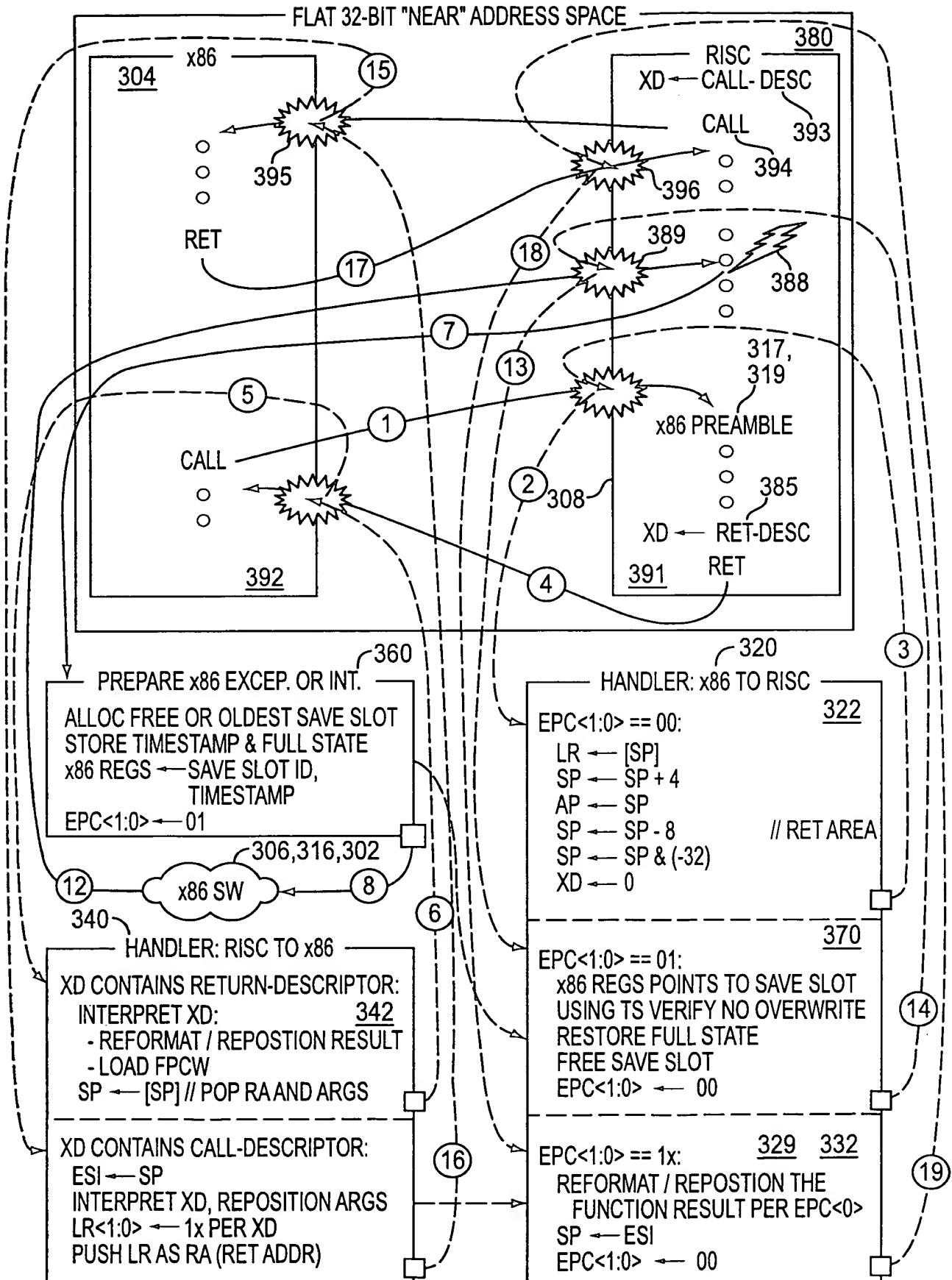


FIG. 3L

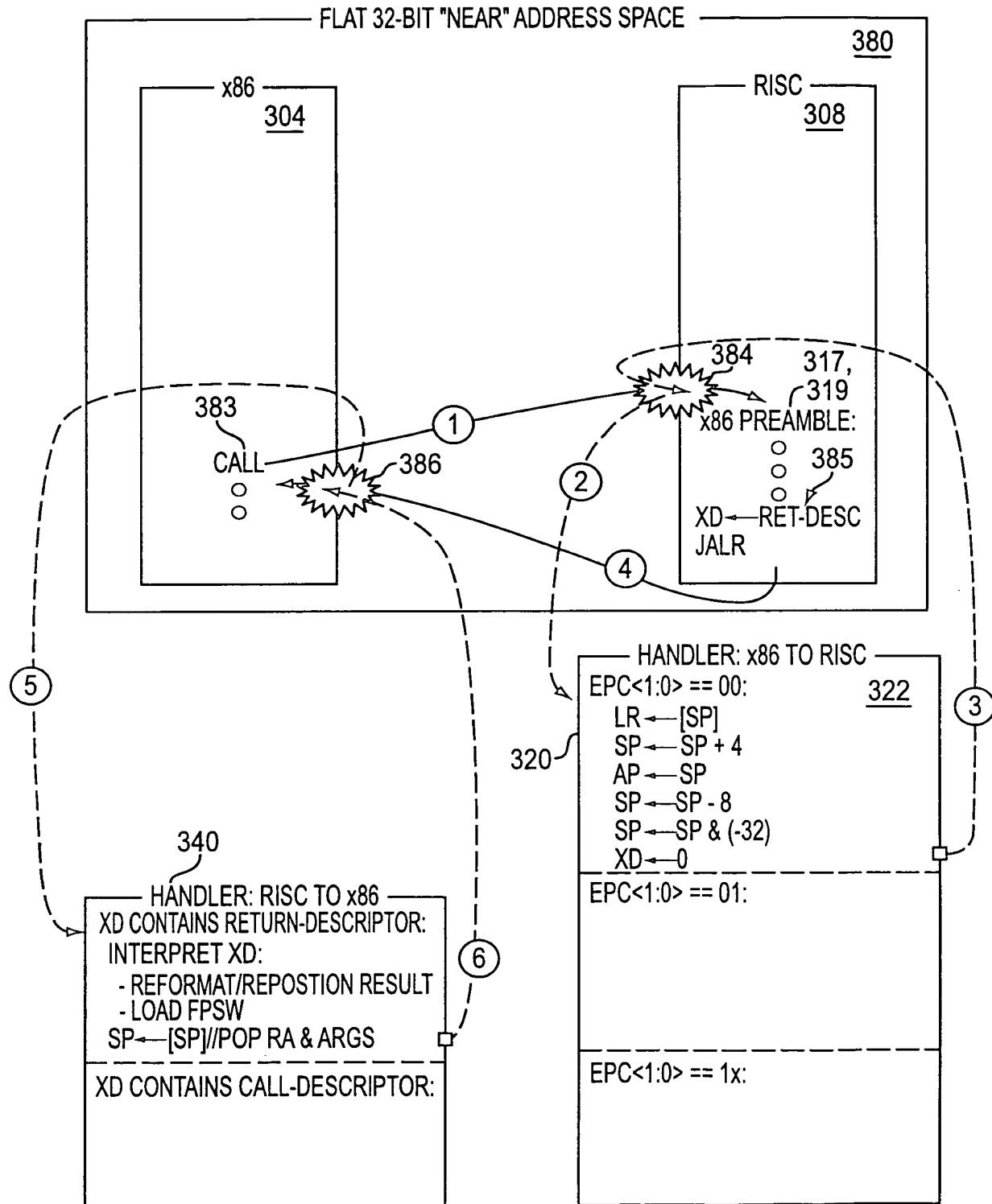


FIG. 3M

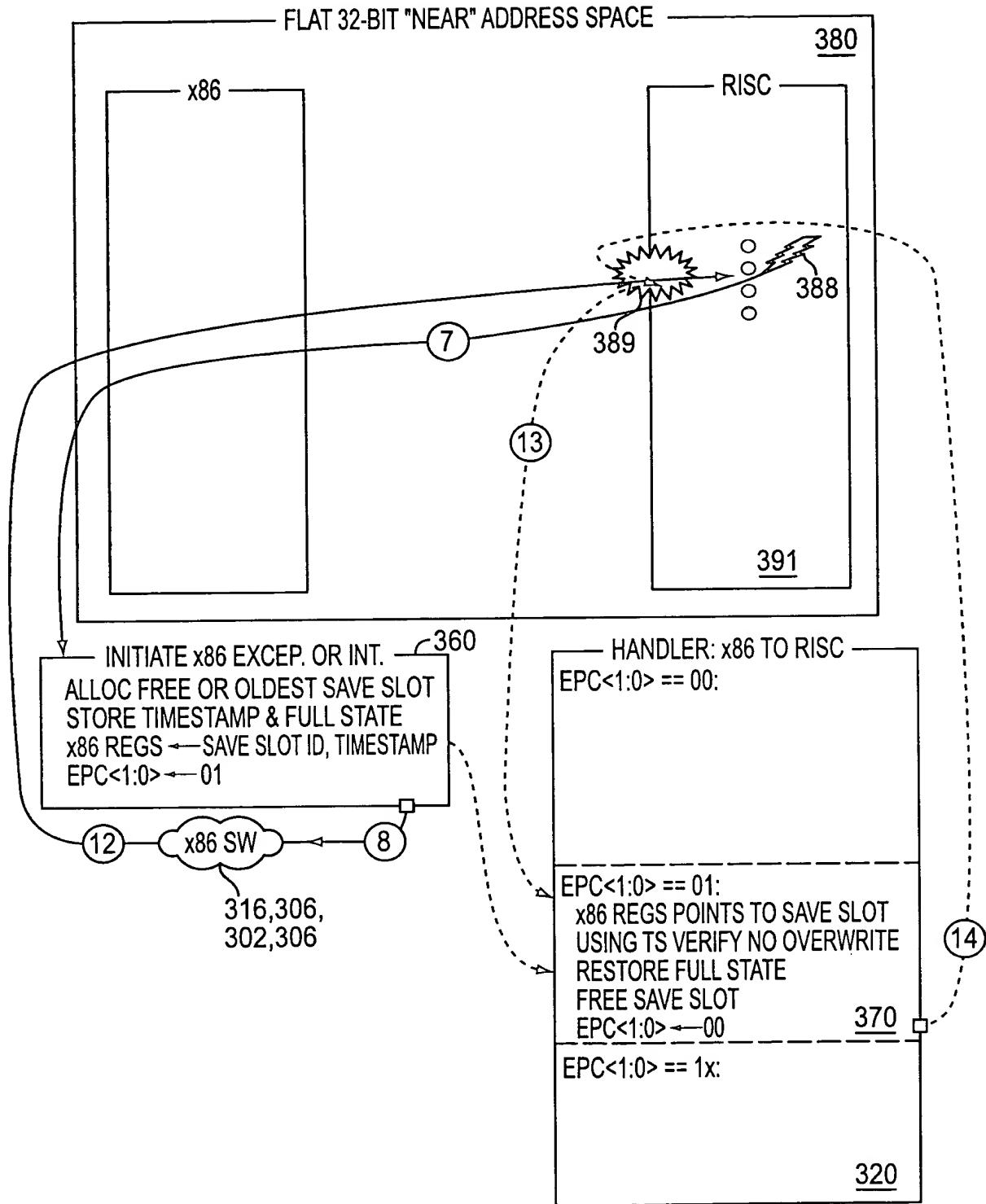


FIG. 3N

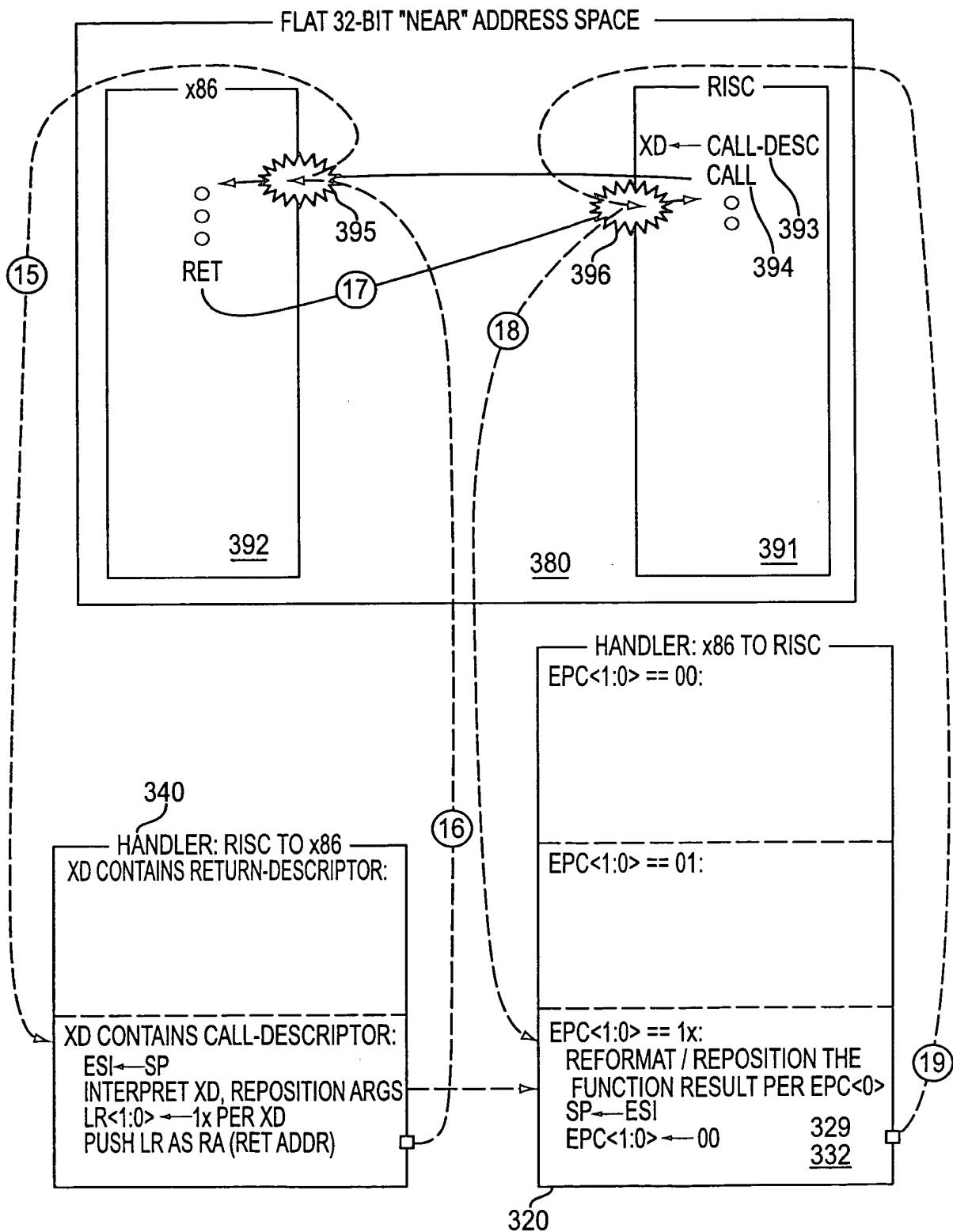
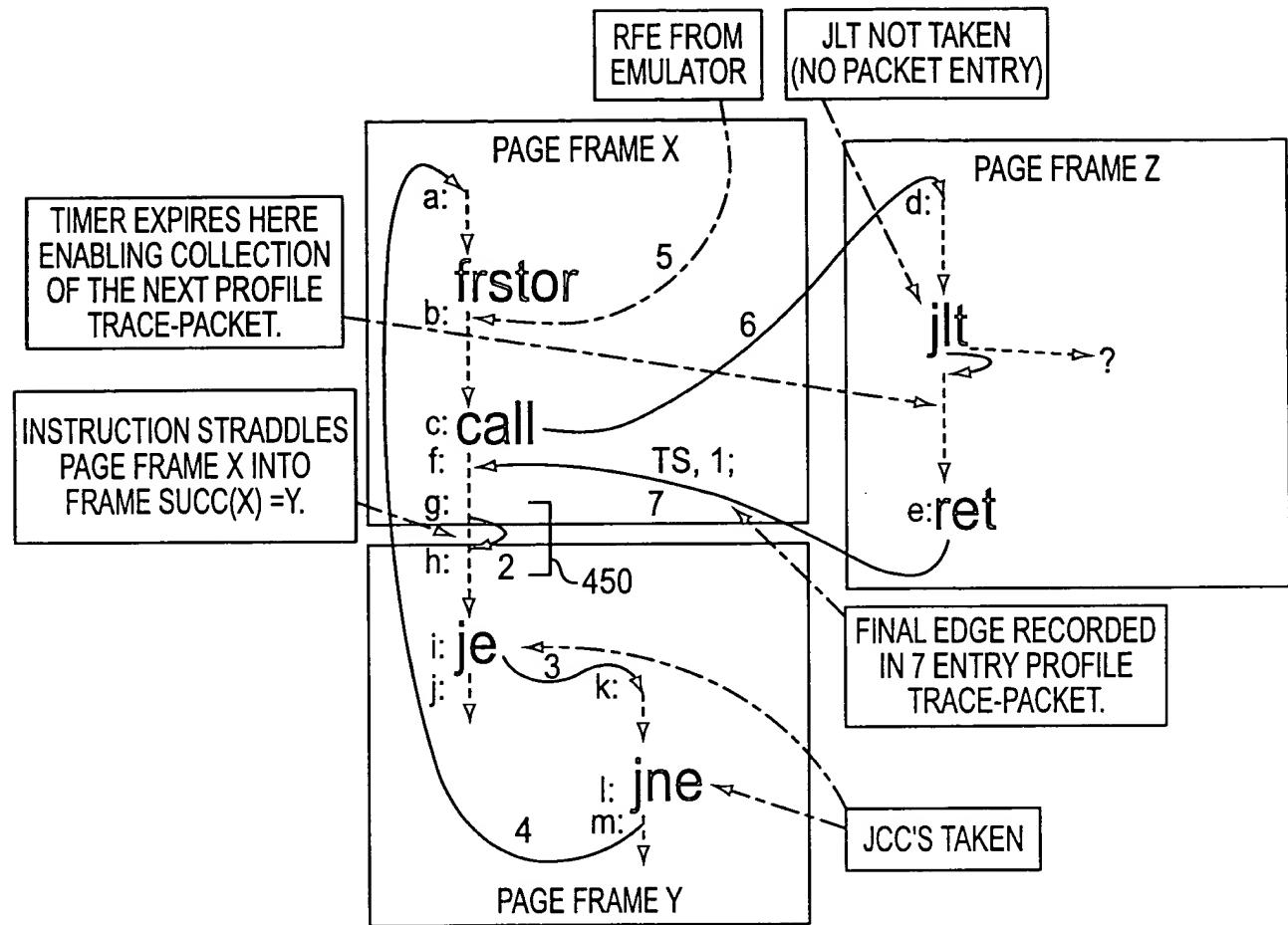


FIG. 30



7 ENTRY TRACE PACKET

ENTRY	EVENT CODE	DONE ADDR	NEXT ADDR
64 BIT TIME STAMP			
1	RET	x86 CONTEXT	phys X:f
2	NEW PAGE	phys Y:g	phys Y:h
3	JCC FORWARD	phys Y:i	phys Y:k
4	JNZ BACKWARD	phys Y:l	phys X:a
5	SEQ; ENV CHANGE	x86 CONTEXT	phys X:b
6	IP-REL NEAR CALL	phys X:c	phys Z:d
7	NEAR RET	phys Z:e	phys X:f

420 {

430 → 430, 454 → 440, 454 → 440 → 440 → 430 → 440 → 440

FIG. 4A

SOURCE	CODE	EVENT	REUSE EVENT CODE	PROFILEABLE EVENT	INITIATE PACKET	PROBEABLE EVENT	PROBE EVENT BIT- ITLB PROBE ATTRIBUTE OR EMULATOR PROBE
	<u>402</u>			414	416	418	610
412	0.0000	DEFAULT (x86 TRANSPARENT) EVENT, REUSE ALL CONVERTER VALUES	YES		NO		REUSE EVENT CODE
412	0.0001	SIMPLE x86 INSTRUCTION COMPLETION (REUSE EVENT CODE)	YES		NO		REUSE EVENT CODE
412	0.0010	PROBE EXCEPTION FAILED	YES		NO		REUSE EVENT CODE
412	0.0011	PROBE EXCEPTION FAILED, RELOAD PROBE TIMER	YES		NO		REUSE EVENT CODE
412	0.0100	FLUSH EVENT	NO	NO	NO	NO	
412	0.0101	SEQUENTIAL; EXECUTION ENVIRONMENT CHANGED - FORCE EVENT	NO	YES	NO	NO	
412	0.0110	FAR RET	NO	YES	YES	NO	
412	0.0111	IRET	NO	YES	NO	NO	
410	0.1000	FAR CALL	NO	YES	YES	YES	FAR CALL
410	0.1001	FAR JMP	NO	YES	YES	NO	
410	0.1010	SPECIAL; EMULATOR EXECUTION, SUPPLY EXTRA INSTRUCTION DATA ^a	NO	YES	NO	NO	
410	0.1011	ABORT PROFILE COLLECTION	NO	NO	NO	NO	
410	0.1100	x86 SYNCHRONOUS/ASYNCHRONOUS INTERRUPT W/PROBE (GRP 0)	NO	YES	YES	YES	EMULATOR PROBE
410	0.1101	x86 SYNCHRONOUS/ASYNCHRONOUS INTERRUPT (GRP 0)	NO	YES	YES	NO	
410	0.1110	x86 SYNCHRONOUS/ASYNCHRONOUS INTERRUPT W/PROBE (GRP 1)	NO	YES	YES	YES	EMULATOR PROBE
410	0.1111	x86 SYNCHRONOUS/ASYNCHRONOUS INTERRUPT (GRP 1)	NO	YES	YES	NO	
404	1.0000	IP-RELATIVE JNZ FORWARD (OPCODE: 75, OF 85)	NO	YES	YES	NO	
404	1.0001	IP-RELATIVE JNZ BACKWARD (OPCODE: 75, OF 85)	NO	YES	YES	YES	JNZ
404	1.0010	IP-RELATIVE CONDITIONAL JUMP FORWARD - (JCC, JCXZ, LOOP)	NO	YES	YES	NO	
404	1.0011	IP-RELATIVE CONDITIONAL JUMP BACKWARD - (JCC, JCXZ, LOOP)	NO	YES	YES	YES	COND JUMP
404	1.0100	IP-RELATIVE, NEAR JMP FORWARD (OPCODE: E9, EB)	NO	YES	YES	NO	
404	1.0101	IP-RELATIVE, NEAR JMP BACKWARD (OPCODE: E9, EB)	NO	YES	YES	YES	NEAR JUMP
404	1.0110	RET/RET IMM16 (OPCODE C3, C2 M)	NO	YES	YES	NO	
404	1.0111	IP-RELATIVE, NEAR CALL (OPCODE: E8)	NO	YES	YES	YES	NEAR CALL
404	1.1000	REP/REPNE CMPS/SCAS (OPCODE: A6, A7, AE, AF)	NO	YES	NO	NO	
404	1.1001	REP MOVS/SSTOS/LDOS (OPCODE: A4, A5, AA, AB, AC, AD)	NO	YES	NO	NO	
404	1.1010	INDIRECT NEAR JMP (OPCODE: FF 14)	NO	YES	YES	NO	
404	1.1011	INDIRECT NEAR CALL (OPCODE: FF 12)	NO	YES	YES	YES	NEAR CALL
404	1.1100	LOAD FROM I/O MEMORY (TLB.ASI I=0) [NOT USED IN T1]	NO	YES	NO	NO	
404	1.1101	AVAILABLE FOR EXPANSION	NO	NO	NO	NO	
404	1.1110	DEFAULT CONVERTER EVENT; SEQUENTIAL <u>406</u>	NO	NO	NO	NO	
	1.1111	NEW PAGE (INSTRUCTION ENDS ON LAST BYTE OF A PAGE FRAME OR STRADDLES ACROSS A PAGE FRAME BOUNDARY) <u>408</u>	NO	YES	NO	NO	

FIG. 4B

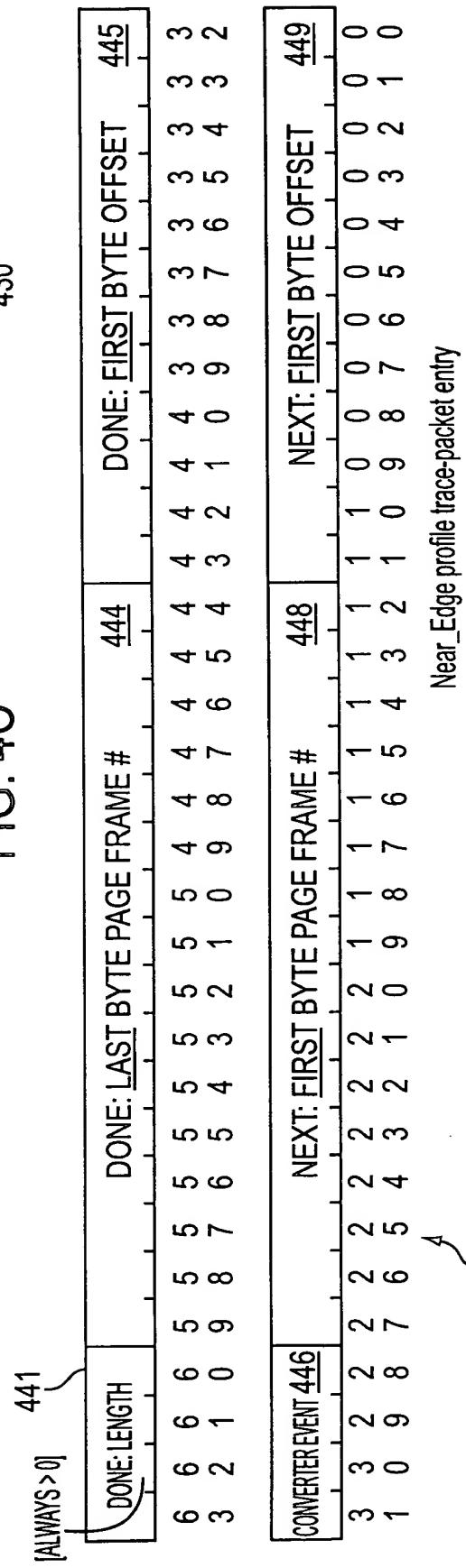
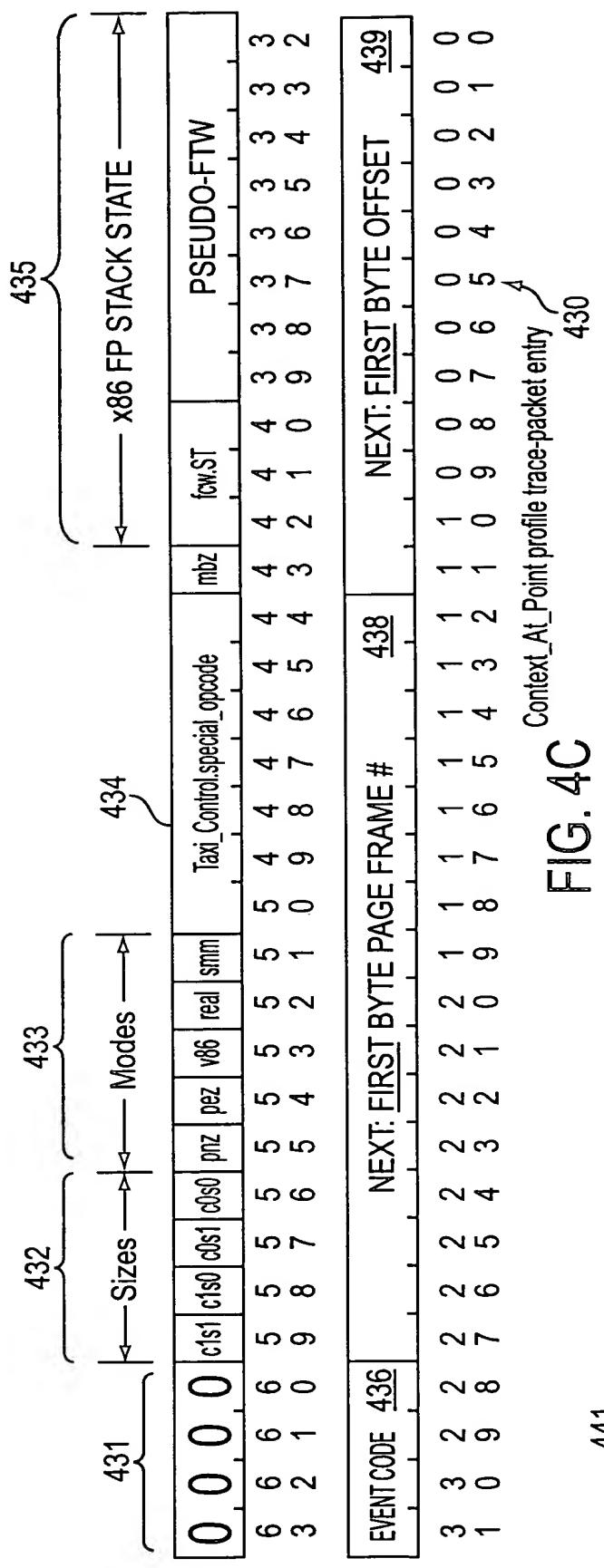
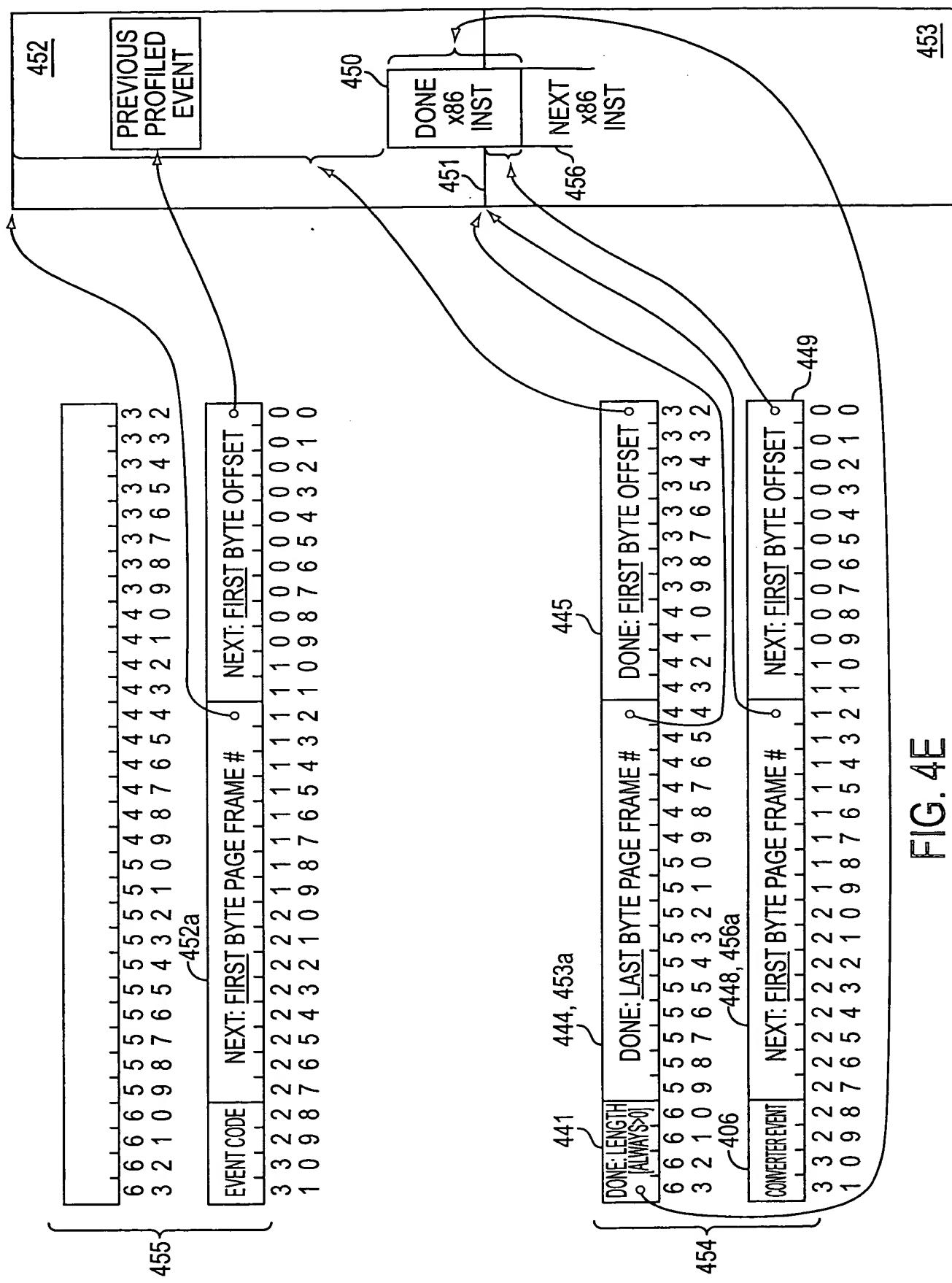


FIG. 4C

FIG. 4D



EIG. 4

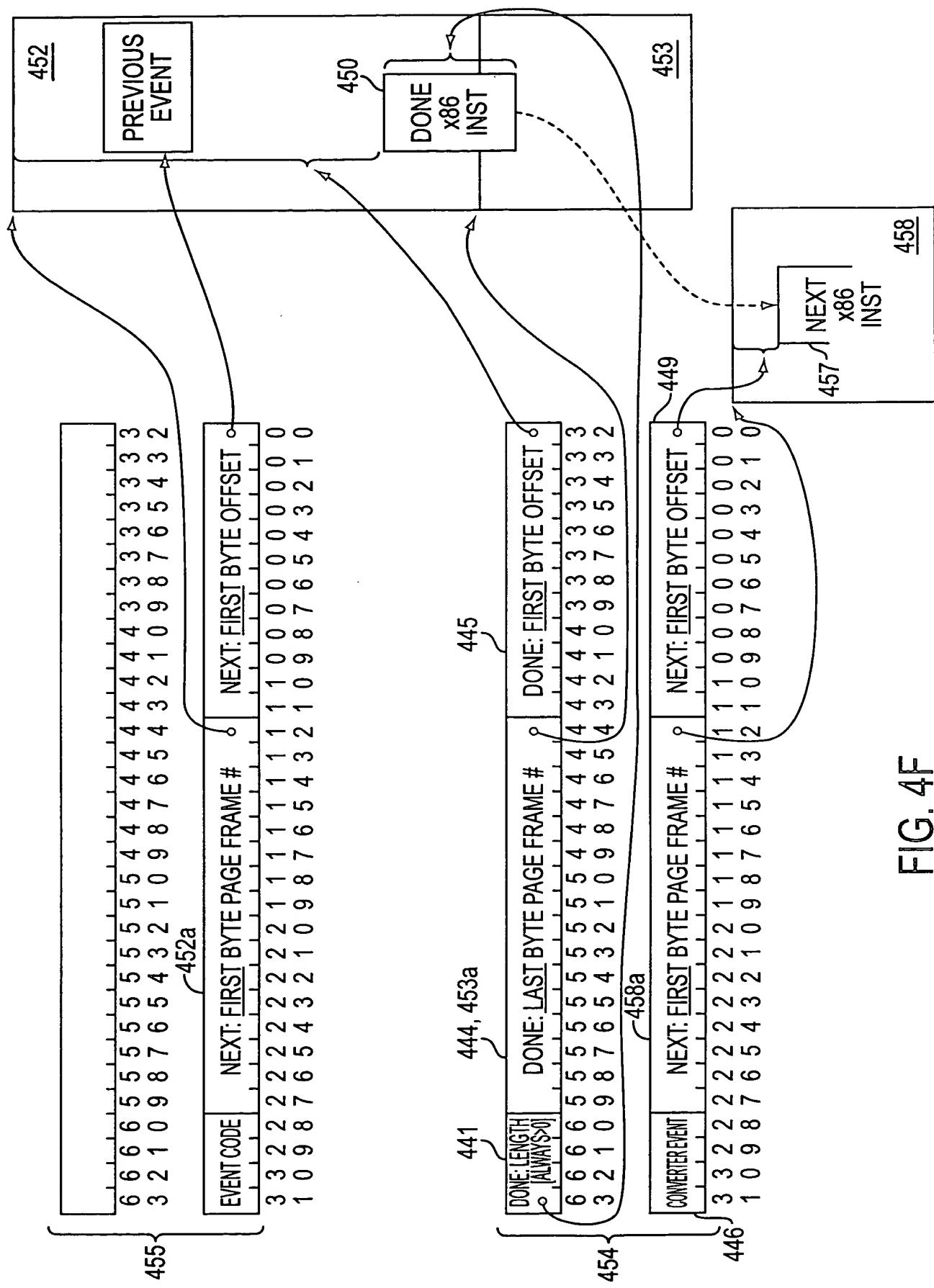
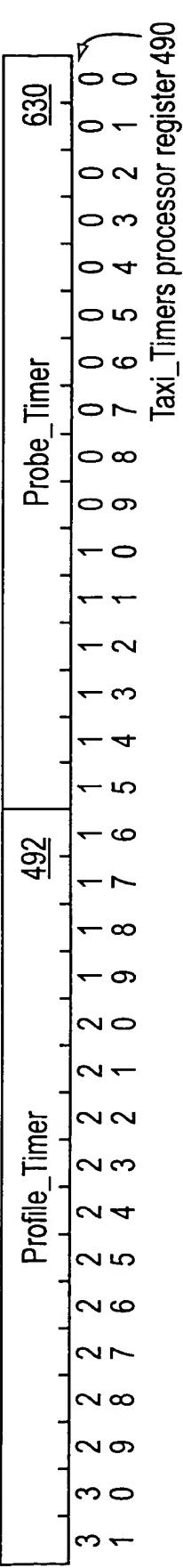
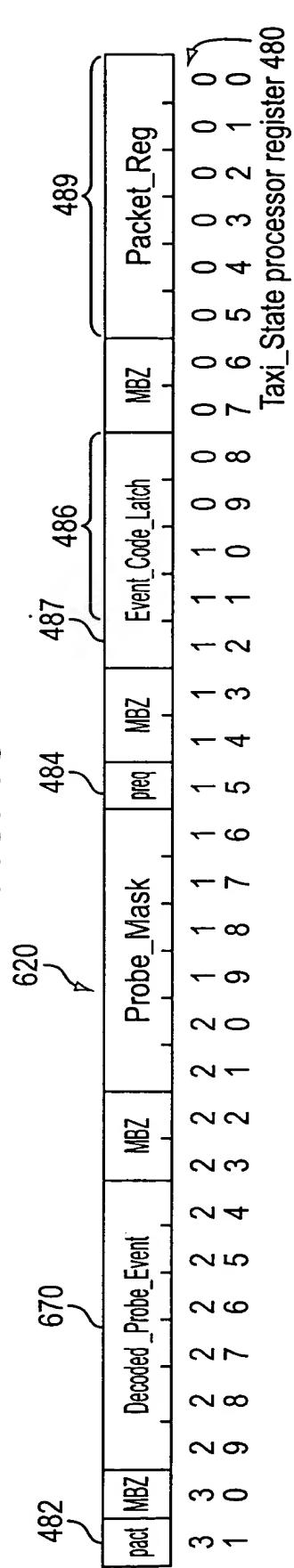
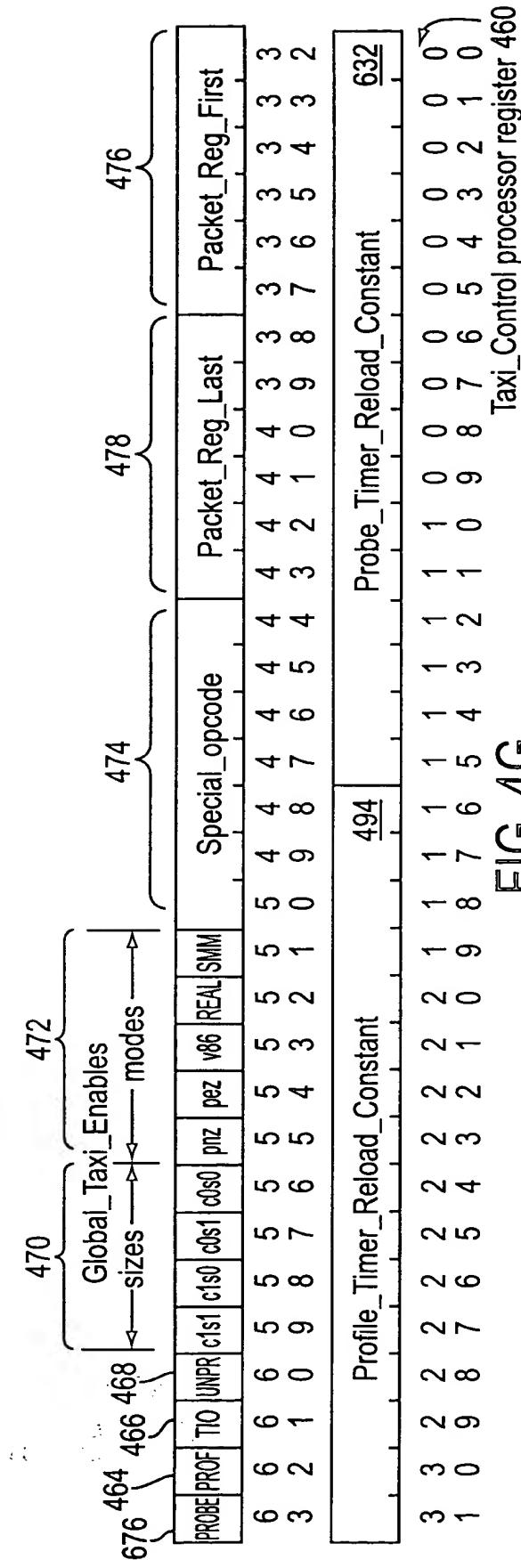


FIG. 4F



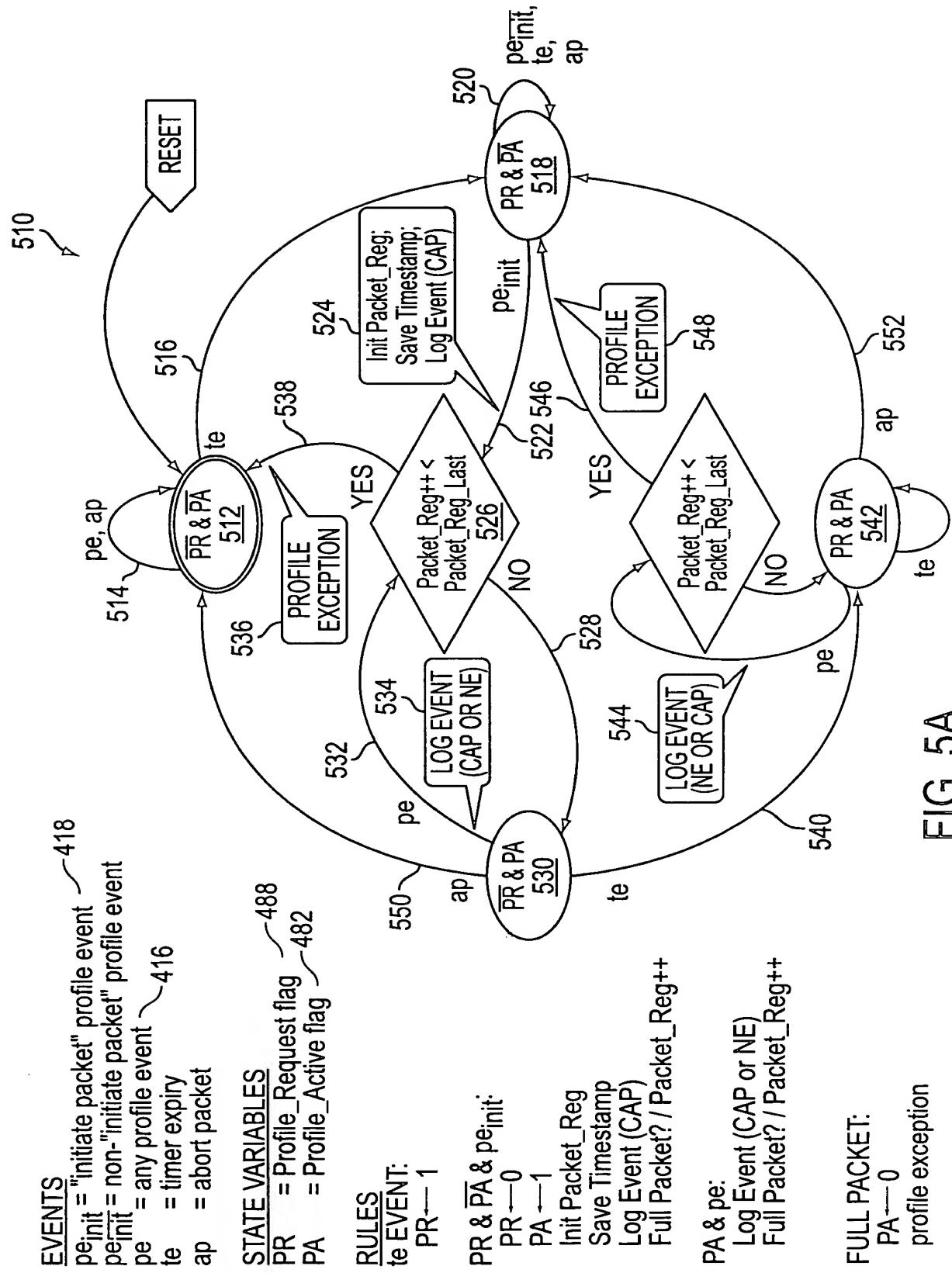


FIG. 5A

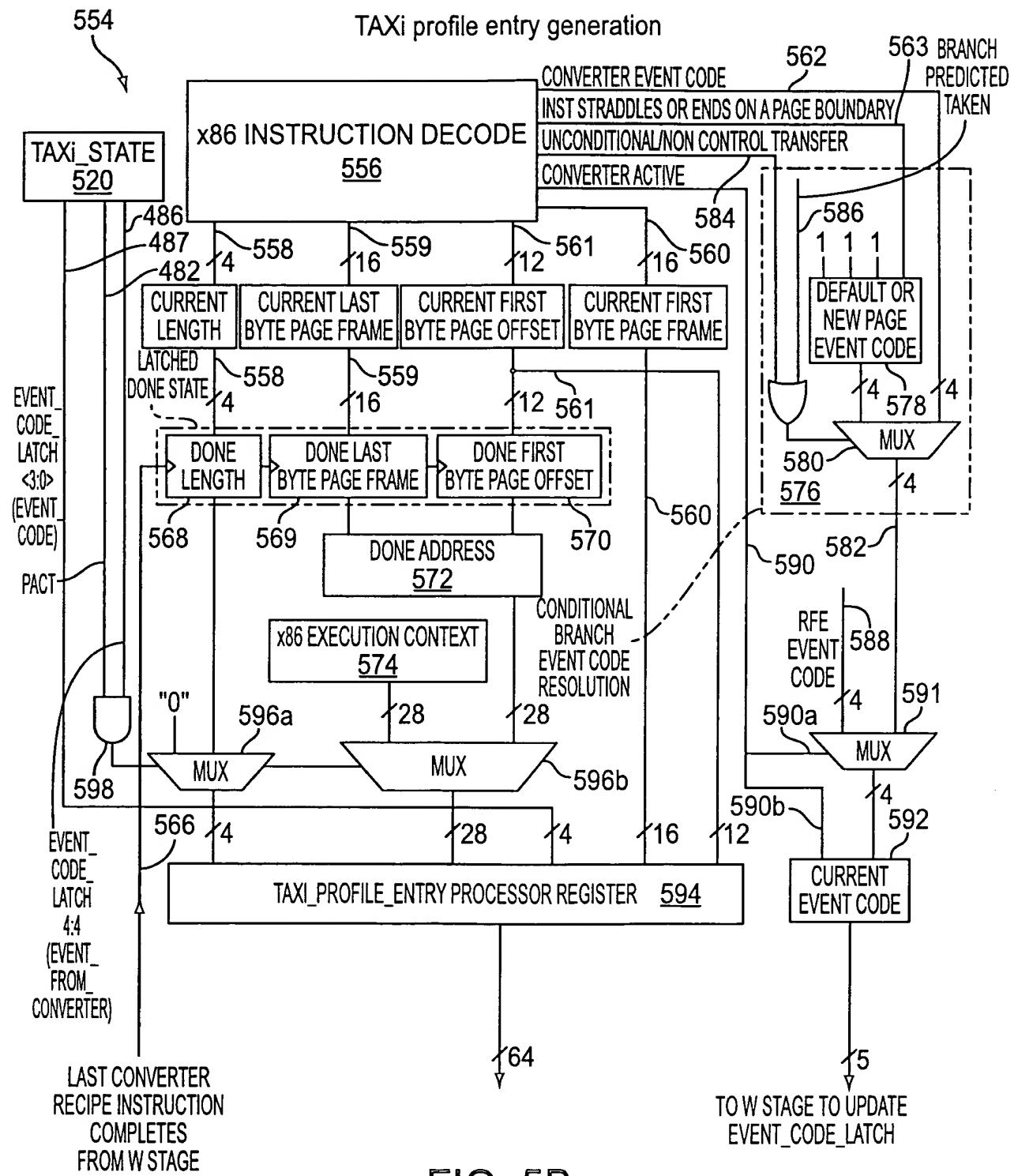


FIG. 5B

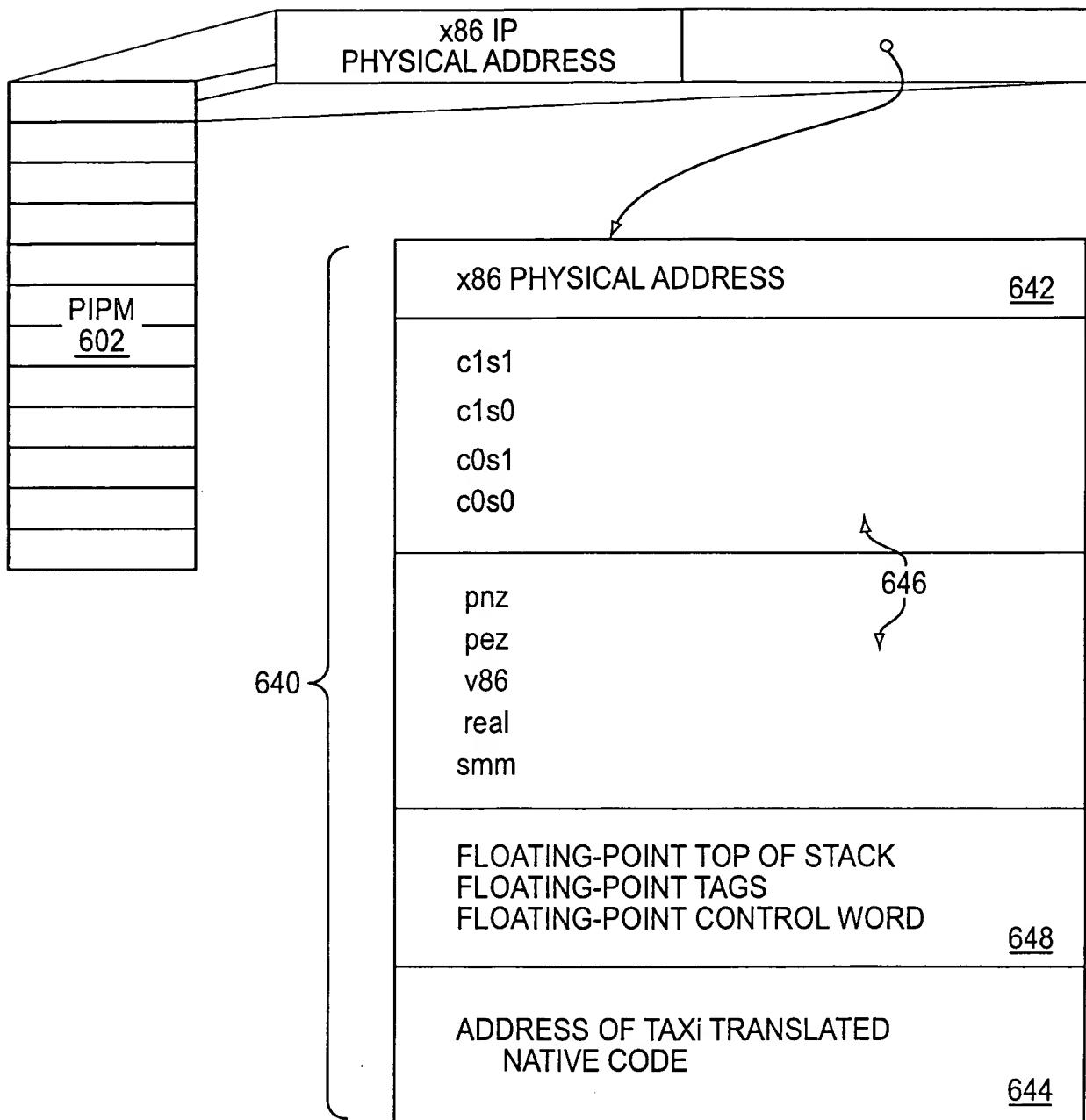


FIG. 6A

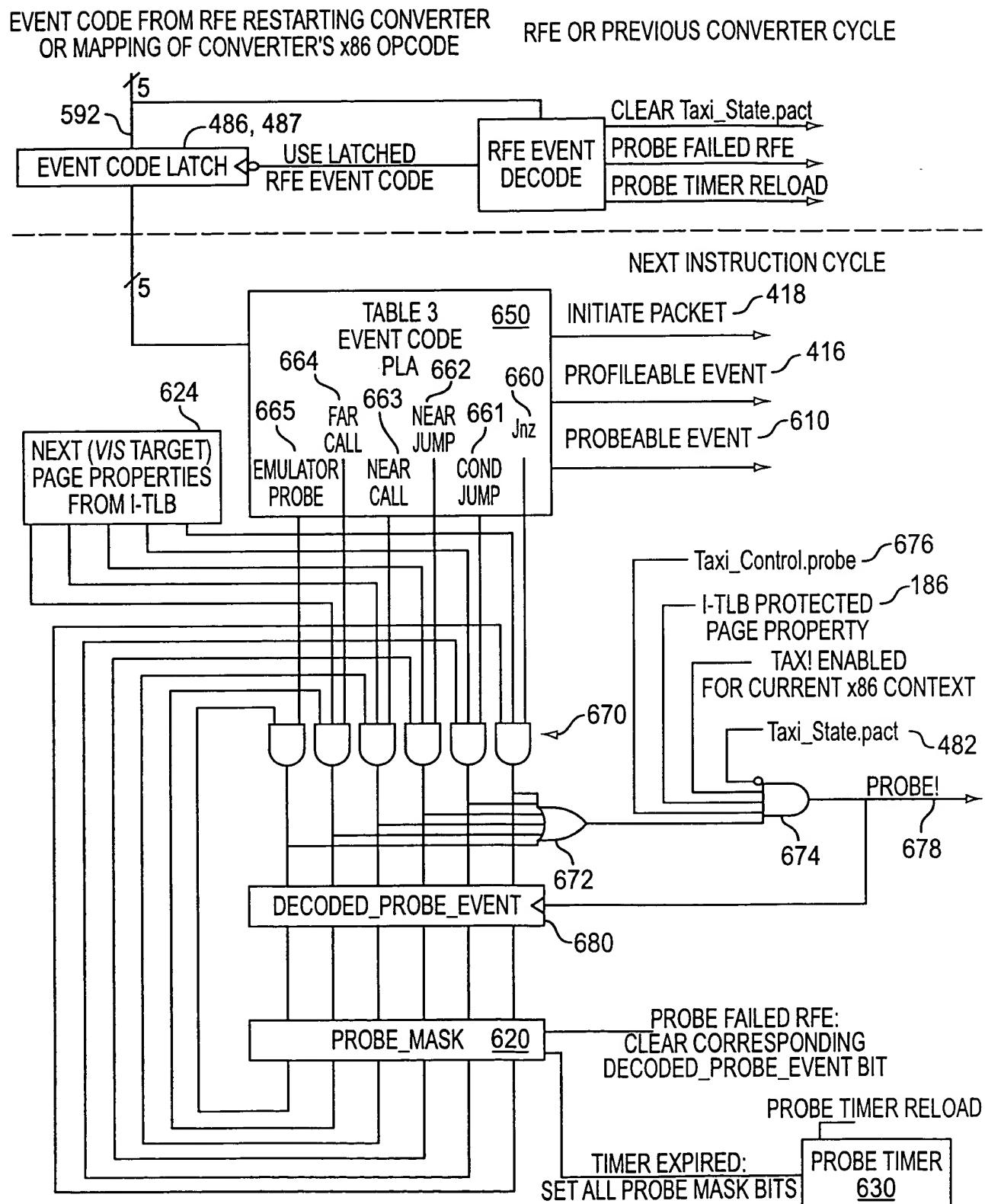


FIG. 6B

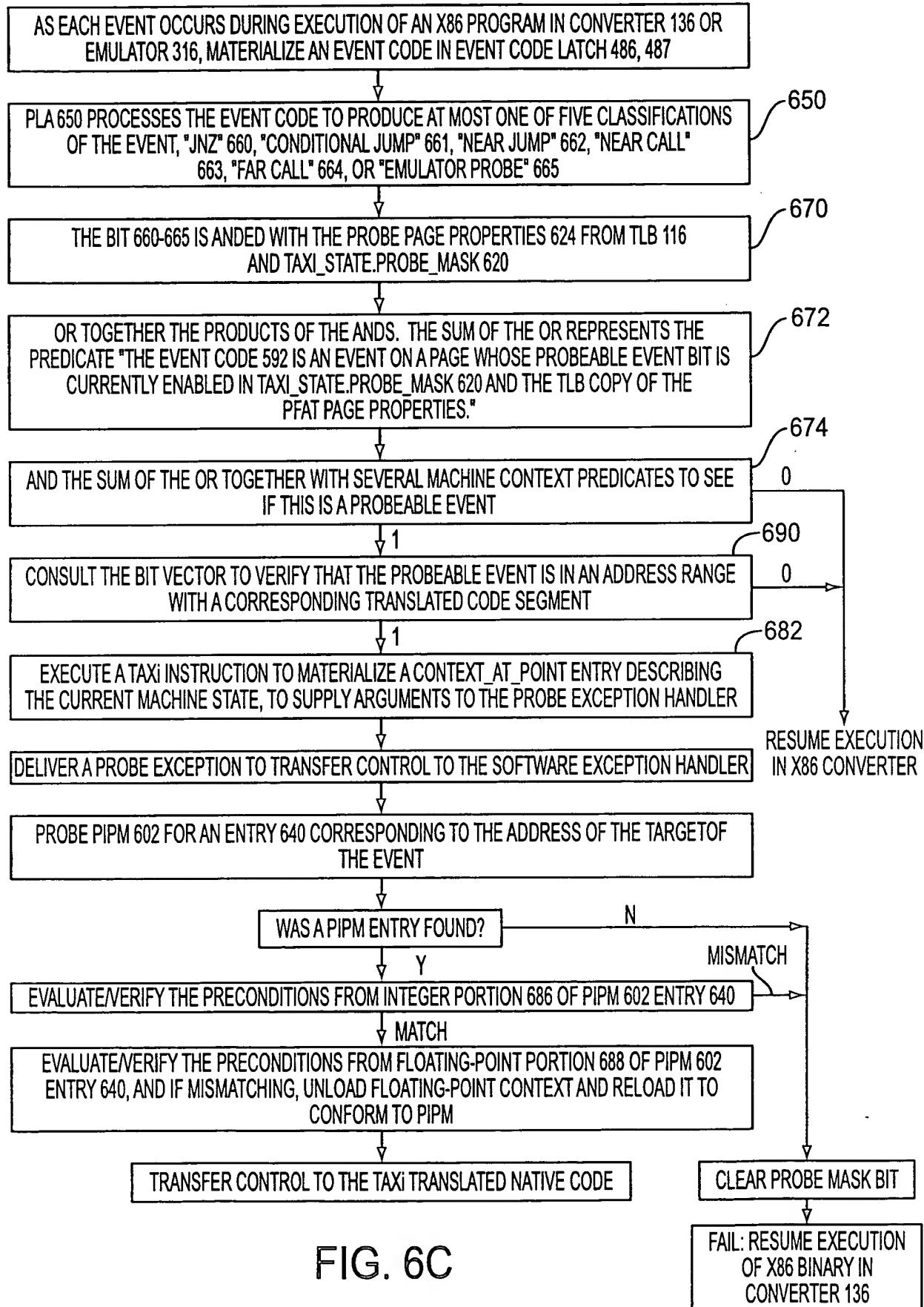


FIG. 6C